2020-06

Assessing soil fertility status and pest infestation levels in selected banana growing regions of Tanzania

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NM-AIST

DISTRIBUTION AND CONSERVATION CHALLENGES FOR A MEDICINAL PLANT *Zanthoxylum chalybeum* AT SIMANJIRO AREA, NORTHERN TANZANIA

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A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Master's in Life Sciences at the Nelson Mandela African Institution of Science and Technology

Arusha, Tanzania

June, 2020

ABSTRACT

Zanthoxylum chalybeum (Rutaceae) is subject to heavy exploitation throughout its areas of occurrence in Sub-Saharan Africa. Despite being a common medicinal plant utilized by a large population, little has been documented regarding the constraints which hinder its promotion and conservation concerns within the country. This study was conducted to determine distribution and conservation challenges facing medicinal plant *Zanthoxylum chalybeum* on different land uses types surveyed at Simanjiro area. The most available roads were used as line transects to observe *Z. chalybeum* distribution in the study area. Plots were established for data collection whereby GPS coordinates (tree presence- absent), tree numbers and anthropogenic threats were the collected information. In addition, open-ended, semi-structured questionnaires and focused group discussions (FGD) were used to capture information on the uses, availability, conservation challenges and management of the plant in the study area. Results indicated that the distribution of *Z. chalybeum* in the area differ significantly across the land-use types surveyed in this study by having many trees in hunting blocks within game-controlled areas and open areas (49 and 40 respectively). Anthropogenic threats signs observed included debarking (51%), branch cut (20.6%) and root digging (15.8%). It was observed that the majority of the households use *Z. chalybeum* for gynecological diseases (such as blood loss after labor, menstrual pain, early pregnancy complications) (86.4%). The main conservation challenges included unsustainable change in land use (99.9%) and inadequate conservation education and awareness. This study recommends more conservation efforts such as active planting of the species, regulated utilization of the *Z. chalybeum* species and increased education and awareness to be implemented by authorities in game-controlled areas and open areas and also conservation education should be provided to members of the community.

DECLARATION

I, Scholastica Dickson Mbinile do hereby declare to the Senate of Nelson Mandela African Institution of Science and Technology that this dissertation is my original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

Scholastica D. Mbinile Date 15/06/2020

Signature
.....

The above declaration is confirmed

Dr. Linus K. Munishi

Signature ..... Date 15.6.2020

Prof. Patrick A. Ndakidemi

Signature ..... Date 15-06-2020

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CERTIFICATION

The undersigned certify that they have read the dissertation titled "Distribution and Conservation Challenges for a Medicinal plant, *Zanthoxylum chalybeum* at Simanjiro area, Northern Tanzania" and recommended for examination in fulfillment of the requirements for the degree of Master's in Life Sciences of the Nelson Mandela African Institution of Science and Technology.

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(Co-supervisor) **Signature** **Date**

ACKNOWLEDGMENTS

I would like to express my gratitude and appreciation to my supervisors; Dr. Linus Kasian Munishi and Prof. Patrick A. Ndakidemi from the Nelson Mandela African Institution of Science and Technology whose tireless guidance and positive comments ensured the successful implementation of the research and preparation of this dissertation.

I am greatly thankful to Dr. Issakwisa Ngondya from the Nelson Mandela African Institution of Science and Technology for his guidance and high contribution to ensuring the research and preparations of this dissertation is achieved.

I am also grateful to Centre for Research, Agriculture Advancement, Teaching Excellence and Sustainability in Food and Nutrition Security (CREATES) for financial support of this research.

Special thanks to my son George Pharles Jr. for being such a calm son. I would like to thank also my beloved family members for their great support, encouragement and prayers.

I would also like to thank Mr. Julius Kimaro (Game Officer) from Tanzania Wildlife Management Authority (TAWA) and Mr. Joseph Shamba (District forest officer) for their support during all periods of the field study.

Last but not least I am greatly indebted to all whose support, encouragement and assistance enabled me to complete this study. However, I apprciate the inspirational and moral support from my friends Warda Kanagwa, Ayoub Assenga, Nanyika Kingazi, Aidan Telesphory and John Sanare and to all of my classmates and friends I couldn't mention all.

DEDICATION

This work is dedicated to my son George Pharles Jr. May God bless him always.

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LIST OF ABBREVIATIONS AND SYMBOLS

%	Percentage
ANOVA	Analysis of Variance
CREATES	Centre for Research, Agriculture Advancement, Teaching Excellence and Sustainability in Food and Nutrition Security
df	Degrees of freedom
DNA	Deoxyribonucleic acid
FL	Farmland
GCA	Game Controlled Areas
GIS	Geographic Information System
GL	Grazing land
GPS	Global Positioning System
km	Kilometer
km^2	Kilometer square
m	Meter
NGO's	Non-Government organizations
NM-AIST	Nelson Mandela African Institution of Science and Technology
OA	Open areas
SHF	Shape file

SPSS	Statistical Package for Social Science
ST	Settlement
TAWA	Tanzania Wildlife Management Authority
χ^2	Chi-square

CHAPTER ONE

INTRODUCTION

1.1 Background of the problem

Medicinal plants are plants that contain compounds beneficial for both human and animal health (Xego *et al*., 2016). Even though there has been an increase in modern health care, over 80% of the global population still depend on medicinal plants as a source of primary health care (McMillen, 2012).

One of the important medicinal plants in Tanzania includes *Zanthoxylum chalybeum* commonly known as 'Oloisuki' and 'Mkunungu' in Maasai and Swahili respectively. *Zanthoxylum chalybeum* (Rutaceae) is a deciduous spiny shrub or tree in Eastern Africa which can grow up to 12 m long. *Zanthoxylum chalybeum* has been reported as an important medicinal plant for malaria treatment, fever, cough, headaches, chest pain, digestive illnesses (e.g. ulcers), diabetes and toothache (Moshi & Mbwambo, 2002; Dharani *et al*., 2010; Laltaika, 2011; Nahashon, 2013; Bbosa *et al.*, 2014; Balama *et al.*, 2015).

Recently, *Z. chalybeum* has been reported in Tanzania as one of the medicinal plants that are under threat of extinction due to excessive exploitation (McMillen, 2012) and thus needs immediate conservation efforts (Nahashon, 2013). Several medicinal plants including *Z. chalybeum* are heavily exploited commercially and locally within the savanna ecosystem (Mahomoodally, 2013; Göhre *et al*., 2016). Apart from their general uses as forage, timber, poles and fuelwood, medicinal plants are also harvested for local uses and export to Europe, the United States of America, Asia and the Middle East (Nahashon, 2013). Despite the vast use of Z. *chalybeum* as traditional medicine, there is a gap in understanding its current distribution and anthropogenic threats, a trend of use, availability, people perceptions on the plant, challenges to conservation and future conservation strategies, such information is crucial for conservation purposes. In Simanjiro areas, the large quantities being harvested from the wild, raising a concern of whether this harvesting is sustainable.

This study, therefore, focused on understanding the distribution of *Z. chalybeum* by mapping its presence-absence in different land uses, it further searched to determine anthropogenic threats facing the tree and also to document the traditional medicinal use, drug preparation, availability, conservation challenges and future conservation strategies of *Z. chalybeum* tree by using a semi-structured questionnaire, focused group discussions and participatory field observation in Simanjiro area. The information generated from this study highlights the challenges facing medicinal plant *Z. chalybeum* in Simanjiro area and thus pave a way for the preparation of *Z. chalybeum* conservation strategy. The study further contributes to information that can assist in developing future management actions and strategies for the conservation of medicinal plant *Z. chalybeum* in the country at large.

1.2 Statement of the problem

Medicinal plant practices are one of the most important practices of plant-based biodiversity. Swai (2003) stated that, almost 75% to 90% of the world's rural individuals depend on wild medicinal plants as a source of health care. The dependence of medicinal plants found in the wild for primary healthcare has resulted in the local extinction of many medicinal plants. Different authors have mentioned the causes of scarcity and endangerment of these plants to be over-harvesting, habitat destruction and poor harvesting methods (Loundou, 2008; McGeoch *et al.*, 2008; McMillen, 2012; Nahashon, 2013; Xego *et al*., 2016). Despite the great richness of medicinal plants in Tanzania, their therapeutic effectiveness and applicability by a large population, fewer researches exist which hinder their promotion and conservation concerns within the country.

In Tanzania, *Z. chalybeum* has been traded locally , while high demand and overexploitation have made it to be among priority medicinal plants for conservation through domestication (McMillen, 2012; Nahashon, 2013; Abihudi, 2014). Many studies have worked only on researching the medicinal values of *Z. chalybeum* looking on chemical extracts, nutrition values, trading and their bioactive compound composition (Anza *et al*., 2014; Augustino & Gillah, 2005; Loundou, 2008; Posthouwer, 2015; Balama *et al.*, 2015).

Despite that the tree has vast values, little information is available regarding its distribution, anthropogenic threats, conservation challenges and management of this important plant. Due to over-exploitation, unsustainable harvesting methods and high demand for this medicinal plant,

there is a danger of it becoming extinct because medicinal plant species are mostly endangered by over-exploitation, land alteration, unsustainable harvesting method and habitat fragmentation. This study aimed at mapping distribution of *Z. chalybeum* in the Simanjiro area, document anthropogenic threats facing the plant, document the uses, availability, conservation challenges and conservation measures of this medicinal plant in the study area.

1.3 Rationale of the study

Medicinal plants have shown to be a source of health care for majority of individuals in the globe. The dependence of local medicines is highly increasing due to the continuance eruption of pandemics. *Zanthoxylum chalybeum* is one of the medicinal plant that is highly exploited in the wild due to its pharmaceutical applicability in many diseases. The high dependence and risks to local extinction of *Z. chalybeum* makes a call for conservation efforts. This study provides a baseline information for conservation of this medicinal plant by providing a distribution map and also outlining anthropogenic threats, conservation challenges and management that can be adopted by Local and other authorities to promote agendas for conservation.

1.4 Objectives

1.4.1 General objective

To determine distribution and conservation challenges for a medicinal plant, *Zanthoxylum chalybeum* at Simanjiro area, Northern Tanzania.

1.4.2 Objectives of the study

(i) To study distribution and anthropogenic threats for a medicinal plant *Zanthoxylum chalybeum* at Simanjiro area, Northern Tanzania.

(ii) To study conservation and management challenges facing a medicinal plant *Zanthoxylum chalybeum* at Simanjiro area, Northern Tanzania.

1.5 Research questions

(i) What are the anthropogenic threats facing *Z. chalybeum* in Simanjiro area?

(ii) How is the distribution of *Z. chalybeum* in different land uses in Simanjiro area?

(iii) What are the uses, availability and conservation measures and conservation challenges of *Z. chalybeum* are there in Simanjiro area?

1.6 Significance of the study

This study informs the community on distribution and conservation concerns on the utilization of *Z. chalybeum* tree to achieve its conservation. Also, the map showing the distribution of the plant provides information to researchers, policymakers and other people on the distribution status of the tree for conservation purposes. The documentation on anthropogenic threats guides conservationists a way forward on conserving the plant by giving suggestions on sustainable harvesting methods to be used. The information in this study also lays a foundation for further research on *Z. chalybeum* and can also be used by policymakers in advocacy medicinal plants conservation programs.

1.7 Delineation of the study

This study conducted field survey, focused group discussion and individual questionnaires to determine distribution and conservation challenges for a medicinal plant, *Zanthoxylum chalybeum* at Simanjiro area, in Northern Tanzania. The field survey involved data collection through road transects and collection of Global Positioning System (GPS) coordinates for producing a distribution map on different land uses types surveyed on the study area.

CHAPTER TWO

LITERATURE REVIEW

2.1 Medicinal plants as a source of health care

Medicinal plants represent a large part of the natural biodiversity of many countries around the globe (Cragg & Newman, 2005). In Africa, traditional medicine is a major socio-cultural heritage as it has been in existence for hundreds of years (Cam *et al*., 2005). Many people in developing countries continue to rely heavily on the use of medicinal plants as their primary source of healthcare (Okigbo *et al*., 2008; Nahashon, 2013). It is found that an estimated 5400 wild-harvested medicinal plant species in Africa, are used as a source of traditional medicine (Okigbo *et al*., 2008). Although there has been an increase in advanced health care systems, 80% of the global population still depend on herbal medicine as a source of primary health care (Lindh, 2015; Swai, 2003). Because medicinal plants are important in the contribution of health care, their conservation is widely needed to assure the plant existence and for the community to continue access to the traditional services provided by the plants.

2.2 Medicinal plants and traditional medicine in Tanzania

Tanzania alone comprises more than 10 000 tree species in which 25% are used as medicinal plant species (Mahunnah & Mshigeni, 1996). The Tanzania Government' Chemical Laboratory has reported a list (not published) of an estimated 500 plants being used as a source of traditional medicine in different parts of the country (Nahashon, 2013). It has been reported that, about 60% of the Tanzania population depend on herbal plants as the source of their primary health care (McMillen, 2012). The traditional care has seen to be reliable by many Tanzanians living in the rural areas of the country in spite of widespread programs to generate health centers and to train Rural medical assistants in those areas (McMillen, 2012). Kaguongo (2012) and Otieno *et al.* (2015) have further reported a thriving medicinal plant trade in both rural and urban parts of Tanzania and the major source of these plants comes from the wild. Wild harvested medicinal plants provide a cure that is cheap and they are readily accessible and available to many people in Tanzania (Hilonga *et al.*, 2019).

2.3 Factors threatening medicinal plants

The exploitation of plant species for medicinal purposes has been responsible for the global decline of some medicinal resources (Mahonge *et al*., 2006; Schippmann *et al*., 2002). The dependence for medicinal plants by a large population of individuals in developing countries has been encountered by unsustainable harvesting of natural plants including those in the wild leading to extinction and endangerment of many plant species (Augustino & Gillah, 2005). It is estimated that 4160 to 10 000 medicinal plants are globally threatened due to unsuitable harvesting methods (Schippmann *et al*., 2002). Additionally, according to Okigbo *et al*. (2008) reliance and demand for timber products, agriculture development, settlements and misuse of wild resources has resulted in the disappearance of many medicinal plant species. Also weakness of regulations that traditionally manage the use of natural resources has been pointed as among the contributions towards threats of medicinal plants (McGeoch *et al*., 2008). According to Elujoba *et al*. (2005) environmental alteration threatens not only the loss of plant resources, but also cultural diversity, traditional community life and the supplementary knowledge of the medicinal value of numerous endemic species.

2.4 Conservation of medicinal plants

As long as habitat destruction and land-use change continue, medicinal plants and their natural environments will remain under the threat of overexploitation than ever before (Nahashon, 2013). To achieve an effective conservation strategy for medicinal plants Okigbo *et al*. (2008) have suggested four main areas to be taken into consideration which are *in-situ* preservation, *ex-situ* preservation, education and research. The *in-situ* preservation includes conservation and establishment of plants and other natural resources in areas within their natural occurrence. *Ex-situ* preservation involves growing conservation in areas outside their natural occurrence such as farmsteads, botanical gardens and home gardens. Nahashon (2013) also suggested the use of an eco-mapping method which will give the community a clear geographical alignment of their land and the right to protect it from the illegal exploitation of natural resources by outsiders.

2.5 Distribution of medicinal plants

Native species especially those with medicinal values are known to be selective to a specific type of environmental condition. Their selectivity has been linked to the carbon-nutrient balance hypothesis which suggests that, organisms with higher concentrations of secondary metabolites such as those of medicinal values are likely to prefer certain environments (Rokaya *et al.*, 2012). Distribution of woody medicinal plant species has also been reported to be influenced not only by anthropogenic factors but also by resource availability (water, nutrients) and disturbance regimes (fire, herbivores) (Sankaran *et al*., 2005).

2.5.1 Role of protected areas on distribution and conservation of medicinal plants

Dudley *et al*. (2010) defined protected areas as "geographical space, recognized, dedicated and managed, through legal or other effective means to achieve the long-term conservation of nature with associated ecosystem services and cultural values". Protected areas have shown to play a vital part in determining the distribution and population of many medicinal plants. Several studies have been conducted to study species richness and distribution within protected areas and have reported the influence protected areas have in species distribution for example; Kaky and Gilbert (2016) found high diversity and distribution of medicinal plants within protected areas compared to nonprotected areas; Newbold *et al.* (2009) and Lee *et al*. (2007) found higher species richness inside protected areas than outside. Therefore, the assumption is being made to find a high distribution of medicinal plant within protected areas compared to nonprotected areas, since the influence in human disturbances is reduced in protected areas.

2.6 Profile of *Zanthoxylum chalybeum*

2.6.1 Botanical description

Zanthoxylum chalybeum is a deciduous spiny shrub or tree of family Rutaceae which can grow up to 12 m long. It has a pale grey-bark color, smooth dark with prickles and scales. The bole of the tree is conical, large and has woody knobs having sharp prickles (June *et al*., 2015). The branches of the tree bear scattered thorns with visible dark scales. The leaves are dark-green in color and usually pairs 3-5 shiny leaflets with a terminal leaflet. Leaflets are oblong to lancelet or elliptic,

2.5-7 x 1-2.5 cm long with a strong citrus aroma once crushed. The petioles of the plant range from 1-5 cm long with small, hooked prickles dispersed along the length (Wunganai, 2016). Flowers have a yellowish-green color with short panicles about 5-10 cm long produced below the leaf at the base of an emerging branch-lets. Fruits are normally reddish-brown in color once ripe (Tshin, 2011). They are about 5 mm in diameter. The seeds have black color once matured (Plate 1) and are characterized by having a hard seed coat and oily causing difficulties in germination.

Plate 1*: Zanthoxylum chalybeum* seeds (A) with seed coat (B) without seed coat

2.6.2 Ecology

Zanthoxylum chalybeum is a tree or shrub (Plate 2) that favors medium to low altitudes in grasslands or dry woodland but often on termite mounds. The tree is native to certain African countries such as Burundi, Congo, Tanzania, Uganda, Zambia, Zimbabwe, Malawi, Democratic Republic of Congo, Kenya, Ethiopia, Namibia and South Africa (June *et al*., 2015). The plant is mostly distributed at medium and low altitudes of 25–1600 m above the sea level. The annual

rainfall of 750 mm to 1500 mm has seen to favor population of these plant species (Wunganai, 2016).

Plate 2: *Zanthoxylum chalybeum* tree (a) (Robert, 2011) and (b) field inventory at Ruvu Maasai hunting block

2.7 *Zanthoxylum chalybeum* and ethno botanical values

2.7.1 Anti-malaria

The ability of *Z. chalybeum* in the treatment of Malaria has been reported in many studies (Dharani *et al*., 2010; Laltaika, 2011; Nahashon, 2013; Bbosa *et al*., 2014). *Zanthoxylum chalybeum* has been reported to contain alkaloids (tembetarine; nitidine and skimmianine) (Fig. 1) which are Anti-malaria secondary metabolites (Wunganai, 2016). Traditionally, the barks of *Z. chalybeum* are harvested, boiled to make a decoction and taken to give relief from malaria symptoms (Laltaika, 2011).

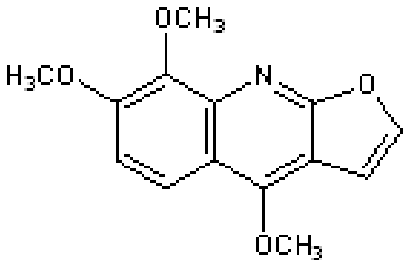

Figure 1: Skimmianine alkaloids in *Zanthoxylum chalybeum* (Wunganai, 2016)

2.7.2 Anti-inflammatory

The study conducted by Müllerjakic *et al*. (1993) showed the presence of the existence of the two benzophenanthridine alkaloids; chelerythrine and nitidine within powder extracts from root barks of *Z. chalybeum*, which both have the chemical ability in reducing swelling. The decoction of powder made from the root bark of *Z. chalybeum* has been used traditionally by herb medicine practitioners in reducing swelling. Presence of protoberberines type of alkaloids were also identified in the bark of *Z. chalybeum*, which were also reported to have anti-inflammatory activities (Matu & Staden, 2003).

2.7.3 Anti-mycobacteria

Zanthoxylum chalybeum has also been reported to contain alkaloids effective in the treatment of respiratory tract infections (Chrian & Otieno, 2011). The dichloromethane extracts from the stem barks of *Z. chalybeum* were found to have anti-mycobacteria activity against tested organisms and this was related to the presence of alkaloids, terpenoids and limonoids which are mycobacteria inhibitors (Chrian & Otieno, 2011).

2.7.4 Anti-diabetics

The study conducted by Agwaya *et al*. (2016) using an extract of *Z. chalybeum* barks showed effectiveness in reducing diabetes by controlling blood glucose and the protection of pancreatic tissues from diabetic damages. Agwaya *et al*. (2016) also reported the root barks of *Z. chalybeum* to have effective prevention ability in the prevention of myocardial damage allied with

type-1 diabetes. Traditionally, roots bark decoction or stem bark decoction are made and taken to treat diabetes. Moshi and Mbwambo (2002) reported that the stem barks of the tree are used to treat diabetes in Tanzania. The ability of *Z. chalybeum* in treating diabetes has been related to the presence of flavonoids and phenolic acids which are responsible for ant-diabetic activity (Ekwemba, 2019).

2.7.5 Anti-fungal

The antifungal activity of medicinal plant *Z. chalybeum* was evidenced in the study conducted by Hamza *et al*. (2006) whereby extracts from plant root barks showed effectiveness in antifungal activities against four types of fungus *Candida krusei*, *Cryptococcus neoformans*, *Candida parapsilosis* and *Candida tropicalis*. The use of *Z. chalybeum* as anti-fungal has also been reported by Olila and Opudaasibo (2001) in their ethnobotanical study conducted by involving traditional medicine practitioners.

2.7.6 Other reported diseases to be cured by *Z. chalybeum*

In ancient China, various plants of *Zanthoxylum* have been used not only as anti-flooding roundworm and tooth pain but also as a flavoring and antiseptic additives (Tian *et al*., 2016). Extracts from a plant are also traditionally used in the treatment of measles, skin infections, sickle cell disease and coughs (Kiringe, 2006; Posthouwer, 2015). The plant has also been reported as an important medicinal plant for fever, cough, headaches, chest pain, digestive disorders (e.g. ulcers), some problems associated with the women reproductive system and toothache (Dharani *et al*., 2010; Laltaika, 2011; Nahashon, 2013; Bbosa *et al*., 2014; Balama *et al*., 2015; Kimani *et al*., 2015).

2.8 *Zanthoxylum chalybeum* as a source of bioactive compounds

The term "bioactive" is a composition of two words: ‘bio’ and ‘active’. In etymology bio comes from the Greek word ‘bios’ which refers to life and ‘active’ comes from Latin word ‘activus’, meaning ‘dynamic, with energy, full of energy, or involves an activity (Guaadaoui *et al*., 2014). They are phytonutrient acting like health-promoting compounds that can lower the risk of different diseases (Krisetherton *et al*., 2012). Different bioactive compounds included in *Z. chalybeum* trunk

and root bark have been reported to have alkaloids (Fig 2) which show a wide range of pharmacological activities (Wunganai, 2016). Different phytochemical investigations done on *Z. chalybeum* showed the presence of skimmianine which according to Chen *et al*. (2005) has cytotoxic activity (anti-tumor and anti-inflammatory activities) and antimicrobial activity (Souza *et al*., 2019). According to Hostettmann *et al*. (2000) skimmianine which is present in medicinal plant *Z. chalybeum* can inhibit or reduce infections and inflammatory or tumors diseases. In different studies conducted by Villalba *et al*. (2007) and Márquez *et al*. (2005) show the presence of ethanolic extracts on the bark of *Z. chalybeum* and presence of ethyl acetate, hexane and ethanolic extracts in the leaves which all give promising results as an anti-inflammatory compound. Moreover, *Z. chalybeum* roots have been reported to contain chelerythrine (a benzo phenanthridine alkaloid) which is potent, cell-permeable protein and selective, which can induce DNA fragmentation and apoptosis (Wink, 2007). Chelerythrine also has active ingredients that contain anti-bacterial activity against *Staphylococcus aureus* (Wink, 2007). Kimani *et al*. (2015) also reported the presence of secondary metabolites within *Z. chalybeum* crude aqueous extracts from stem barks such as alkaloids, flavonoids, terpenoids, saponins, tannins, tembetarine, nitidine, phenols and glycosides.

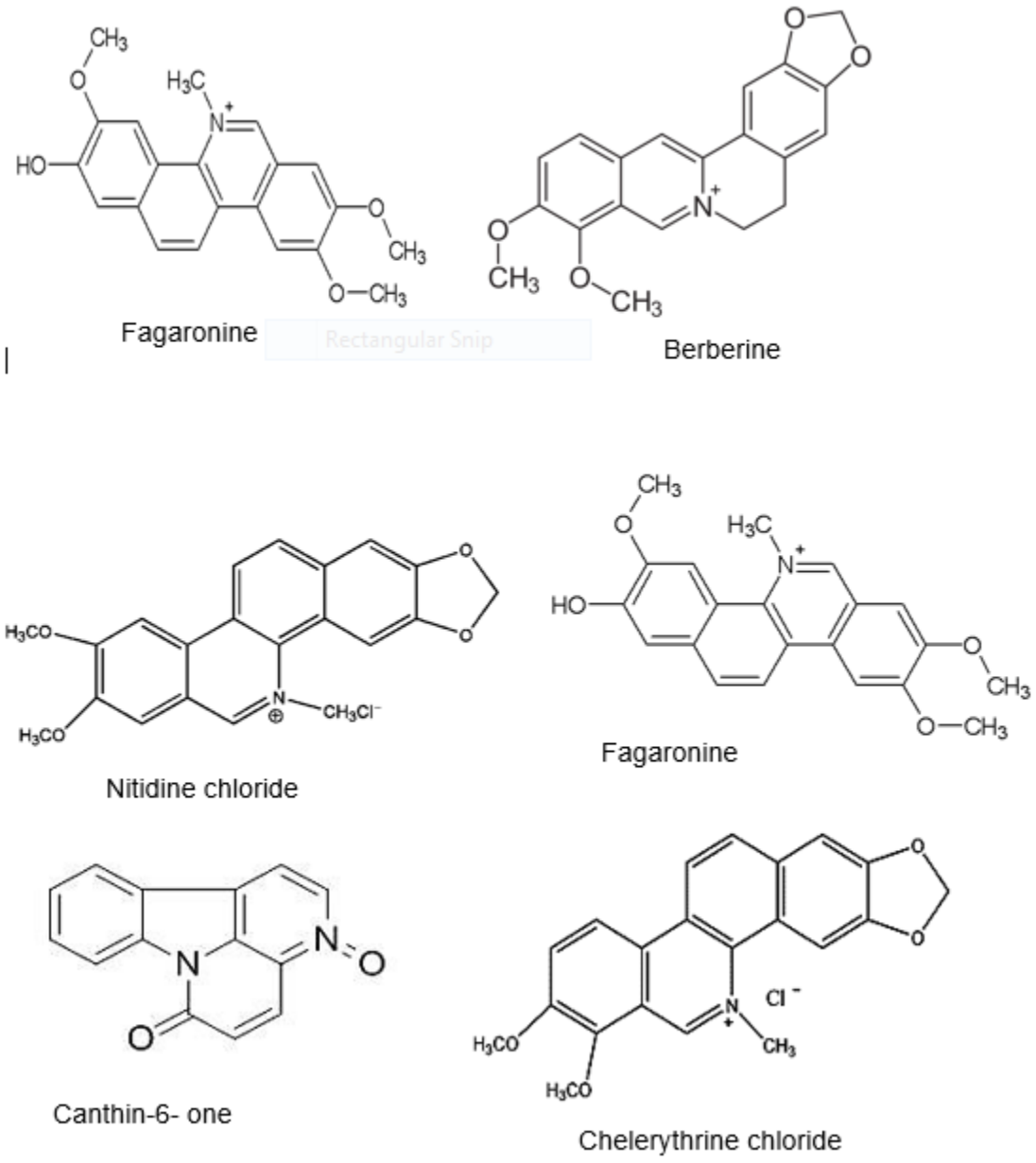

Figure 2: Structure of some chemical alkaloids found within *Zanthoxylum chalybeum* (Adesina, 2005)

2.9 Other uses of medicinal plant *Zanthoxylum chalybeum*

Apart from medicinal values *Z. chalybeum* has also been reported to be harvested for other local uses. The leaves of the plant have been used as a vegetable (Balama *et al*., 2015) while the leaves and fruits have also been used as fodder to goats (Bbosa *et al.*, 2014). The plant has also been used

as a source of charcoal, timber, utensils making including spoons, combs and carvings, fencing and firewood (Bbosa *et al.*, 2014; Balama, 2016). Leaves and fruits of the tree have also been used for mouth wash and tooth care while stem barks are used for fish intoxicating (Bbosa *et al.*, 2014).

The review above shows how important *Z. chalybeum* and medicinal plants at whole are to the community. Therefore, more researches and documentation are needed in order to emphasize the conservation and sustainability of this important biodiversity resource so that the community should continue to receive and use the plants for millenniums to come.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the Study area

Simanjiro District of Manyara Region in Northern Tanzania lies between 3°52' and 4°24' South and 36°05'and 36°39' East (Nyaruhucha *et al.*, 2006). It falls into ecological zone IV (Pratt *et al*., 1966) with a semi-arid climate and has an alkaline soil with an average pH of 7.7. The district borders Tarangire National Park to the Eastern side. The district has an annual rainfall of 650 mm per annum while its temperature varies between 18-30°C. Simanjiro district covers about 19 928.1 km^2 and most of its area is covered by open woodland, bushy forests and grassland vegetation (Nyaruhucha *et al*., 2006). The area lies within the Maasai Steppe with an area of 20 591 km^2 of which 600 km^2 of the entire steppe is a fertile land for agriculture while 12 682 km^2 is covered by Game Controlled Areas and Open areas and the rest is a hilly area (Nyaruhucha *et al.*, 2006). The main vegetation types are grassland (51%) composing of short *Digitaria macroblephara* and *Panicum coloratum* species. Twenty-six per cent of the vegetation is covered by wood vegetation mainly *Acacia stuhlmannii* and *Acacia drepanolobium* (Msoffe *et al*., 2010). The main economic activities in the area include livestock keeping, farming and hunting.

3.2 Sampling design and data collection

3.2.1 To study conservation and Management Challenges facing a medicinal plant *Z. chalybeum* in Simanjiro area, Northern Tanzania

The study was conducted from July 2019 to January 2020. Purposive sampling method was used in this study to collect information on conservation and management challenges facing a medicinal plant *Z. chalybeum* from five selected Villages and Wards (Terrat, Loiborsoit A, Londrekess, Naberera and Namalulu). The villages were selected as they have been known to natively have the tree compared to other areas in the district. The selection of individual respondents was based on the knowledge of the individual about *Z. chalybeum* tree, be a resident in the area for more than ten years and be willing to share the intended information. To study plant availability, traditional uses, conservation challenges and future conservation strategies, open-ended, semi-structured questionnaires were administered to selected local participants from the selected villages, as well

as engagement of focused group discussion (FGD). The FGD was formed with individuals who were willing to participate in the interview discussion and by making sure there is a balance between men and women. The information from FGD was taken after the agreement was reached between the participants and was regarded as single information. Respondents were asked to identify the possible therapeutic uses of *Z. chalybeum* plant, the plant parts harvested and method of use, the preference of use, rate of pant availability (whether increasing or decreasing), conservation challenges and conservation measures that can be adopted to ensure *Z. chalybeum* plant sustainability. Key-informant interviews were administered to elders (above 60 years old), district forest officer and a member from Non-Governmental Organizations (NGO's) which deals with conservation. The rate of preference for the *Z. chalybeum* plant for medicinal uses compared with other medicinal plants as a source of local remedy to the community was also explored. A total of 110 respondents (103 respondents from the local interview and 7 key informants) following Israel (1992) formula. A trustee translator was involved in translating the information where respondents used the local language (Maasai) to ensure that all the information given by respondents was captured.

3.2.2 To study distribution and anthropogenic threats for a medicinal plant *Zanthoxylum chalybeum* in Simanjiro area, Northern Tanzania

A preliminary survey was conducted from June to July 2019 to identify the land use types present at Simanjiro area for data collection. A district forest officer was involved to ensure easy identification and demarcation of villages in different land use types surveyed in the study area. The most available roads were used as line transects to observe *Z. chalybeum* distribution in the area. The use of roads as transect was selected because the study involved study in a large area and on dispersed tree population as recommended by Buckland *et al*. (2005). A buffer off-road walk distance of about 50 m from the transect (road) to the interior was established to reduce edge effect and bias in observation. A systematic sampling technique was employed in the study whereby at least every 1 km distance, a sampling plot of 20 m radius was established for data collection (Buckland *et al*., 2005). A total of 501 sampling plots were established during the study (89, 119, 113, 71 and 109 plots for farmland, game-controlled area, grazing lands, open areas and Settlement areas respectively) on which coverage of plots depend on the size of the land use type. Assessment of anthropogenic threats signs, number of *Z. chalybeum* trees and record GPS coordinates of

sampled plots and data were collected during the field study. Scaling of damage per tree was scaled from 0-3 were; (0)-no damage, (1)-slight damage-few scars, (2)-severe damage-scarred deeply and (3)-tree completely damaged-dead (Sukopp, 2004). Global Position System (GPS) Garmin 64S a handheld device was used to attain coordinates on tree present- absent data while a self-made data collection sheet was used to record the observed anthropogenic threat signs.

3.3 Data analysis

Spatial distribution data of *Z. chalybeum* in the study area were examined using Arc GIS (Arc Map version 10.6) to produce the distribution map (Huang *et al*., 2016). To analyze *Z. chalybeum* distribution, the GPS coordinates recorded during data collection and the patterns of this in the entire study area were compiled then converted to shapefiles (SHP) format. The different (range) categories of distribution and threats and analyzed patterns of change across the entire study area were also compared. The Kernel density tool in the arc map version 10.6 was used to calculate the spread and spatial distribution pattern of *Z. chalybeum* across the landscape to create a continuous surface with a search radius of 1 km. Kernel tool calculated density units based on the linear unit of the projection of the output spatial reference. Chi-square test was performed using STATISTICA Version 8 at a 5% level of significance to compare frequencies of anthropogenic threats in different land uses. One-way analysis of variance (One way-ANOVA) was used for the analysis of presence-absence data on sampling points at a 5% level of significance. The collected data through semi-structured questionnaires were first interred and coded in Microsoft Excel on the computer. Information collected through focused group discussions were synthesized and summarized into meaningful units. The data were then cleaned to facilitate analysis. Statistical Package for Social Science (SPSS) computer program version 21 was used to analyze the data. Chi-square test was used to test the significant relationship between plant part harvested and the disease reported at 0.05 level of significance. Microsoft Excel (version 2013) was used for graphical representations. Descriptive statistics such as frequencies and percentages were computed and defined to form a discussion.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Characteristics of respondents during the interview

A total of 103 local respondents; 54.4% and 45.6%, female and males respectively were engaged in this study. The majority of respondents were between the age of 31-60 years old (61.2%), while the minorities were between 18-30 years old (23.3%) and above 60 (15.5%). The study revealed that most of respondents had primary education level (53.4%), secondary level (14.6%) and adult education (6.8%) while 25.2% did not attend school at all. 44.7% of respondents were engaged in pastoralism as their occupation, while 30.1% were housewives and (17%) engaging in small businesses (Table 1).

Table 1: Socio-demographic characteristics of respondents in the study area

Characteristic	Frequency	Percent
Gender		
Male	47	45.6
Female	56	54.4
Total	**103**	**100.0**
Age		
18-30	24	23.3
31-60	63	61.2
Above 60	16	15.5
Total	**103**	**100.0**
Education level		
Primary level	55	53.4
Non	26	25.2
Secondary level	15	14.6
Adult education	7	6.8
Total	**103**	**100**
Occupation of respondent		
Pastoralist	46	44.7
House wife	31	30.1
Small business	17	16.5
Game officer	3	2.9
Teacher	3	2.9
Jobless	3	2.9
Total	**103**	**100**

4.1.2 Information on the uses of the plant and harvesting methods

The most frequently ailments mentioned by respondents to be cured by *Z. chalybeum* tree are; gynecological diseases (such as blood loss after labor, menstrual pain, early pregnancy complications) (86.4%), Body ache (68%), fever (53.4%), chest pain (48%) and pneumonia (62.1%). Other mentioned ailments include general body immunity against diseases (19%), dizziness (15%), Malaria (10%) and abdominal pain (9%) (Fig. 3). According to respondents the *Z. chalybeum* is preferred by all group of people (men, women and children), but women are mostly using the plant after delivery to stop blood loss and reduce labor pain (76.7%). There was a strong relationship between plant part harvested and the disease mentioned to be cured (x^2 =408.8, df = 24, p = 1.16e^{-7}).

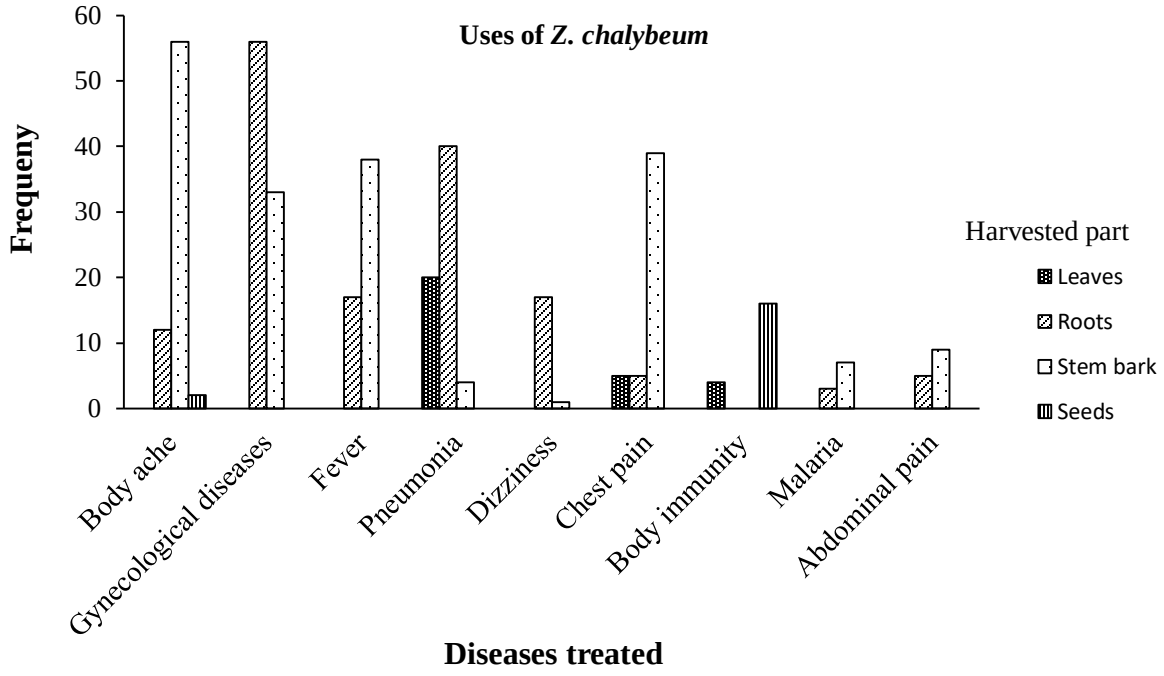

Figure 3: Reported diseases that can be treated by *Z. chalybeum* and the plant part being used

Ninety percent (90.3%) of respondents agreed to prefer *Z. chalybeum* compared with other medicinal plants because of its efficacy in treating diseases. Respondents also mentioned other uses of the plant to be beverage (porridge and tea) spice (83.5%), ruminant fodder (especially seeds) (58%), Boma fencing (30%) and as firewood (11.6%). According to respondents root digging (93.2%), bark stripping (84.5%), seeds harvesting (67%) and leaves pruning (56.3%) are the main methods used for harvesting while wilting, plant death, stunted growth and exposure to insects' damage are the effects mentioned by respondents (85.4%, 20.4%, 15.5% and 31.1% respectively) resulting from excessive and unsustainable harvesting methods (Fig. 4).

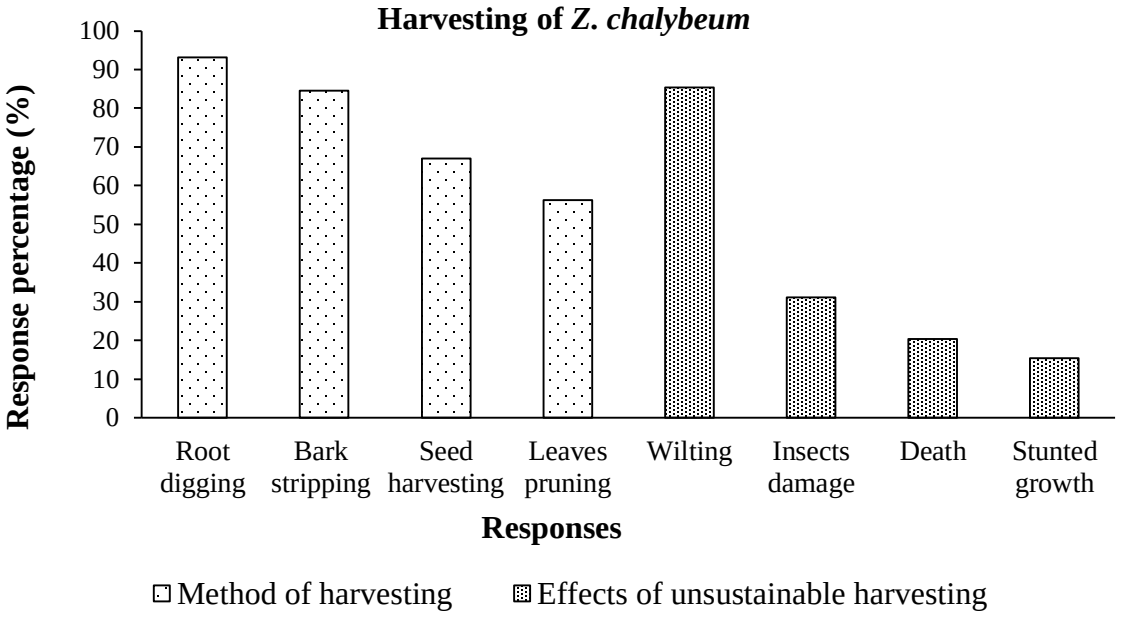

Figure 4: Methods of harvesting and the effects caused by unsustainable harvesting methods used by community members at the study area

Majority of respondents mentioned roots and stem bark as the most used plant parts (90.3% and 81.6% respectively) for remedy preparations while seeds and leaves were the least (58.2% and 31.1% respectively) meanwhile boiling was reported as the main method (62%) for medicine preparation while drying (32%) and eating raw (6%) were the least mentioned methods (Table 2). The reasons given by respondent on the preference of roots and stem bark over other parts was due to long term belief or knowledge (59%) more curative (stronger medicinal effects) (77%) and the full-term availability (64%).

Table 2: **Diseases treated, harvested part, mode of use and preparation of *Z. chalybeum* tree as a medicine**

Disease treated	Plant Part harvested	Method of use and preparations
Fever	Roots	Wash, boil/ soak in water and drink
Gynecological diseases (blood loss after labor, menstrual pain, early pregnancy complications)	Roots and stem bark	Wash, boil together and drink the juice while hot
Dizziness	Roots	Wash, boil and drink
Body ache	Stem bark	Boiled and drink
Malaria	Stem bark	Boil and drink
Pneumonia	Roots	Boil and drink while hot
Chest pain	Leaves and stem bark	Chew the raw leaves, boil the barks and drink the juice
Abdominal pain	Roots	Boil/ soak in water make a juice and drink
Body immunity	Flowers and seeds	Dry the parts harvested, grind and mix in other beverage either milk, tea or porridge, use daily

4.1.3 Information on preference between traditional medicine and modern health care

Eighty nine percent of respondents agreed to prefer traditional medicine over modern medicine (11%) and this is because traditional medicines are cheaper than modern medicines (89.3%), safer (83.4%), unavailability of adequate modern care systems (76.6%), conserving their tradition (50.4%), accessible (71.8%) and presence of varieties of medicinal plants (29.1%) (Example; Olkitalaswa (*Myrica salicifolia*), Orbukoi (*Terminalia brownii*), Osokonoi (*Warburgia ugandensis*), Olkiloriti (*Acacia nilotica*), Ormukutan (*Albizia anthelmintica*) and Olgumi (*Vangueria apiculata*)) among which Oloisuki (*Zathoxylum chalybeum*) is more harvested compared to the rest mentioned (Fig. 5).

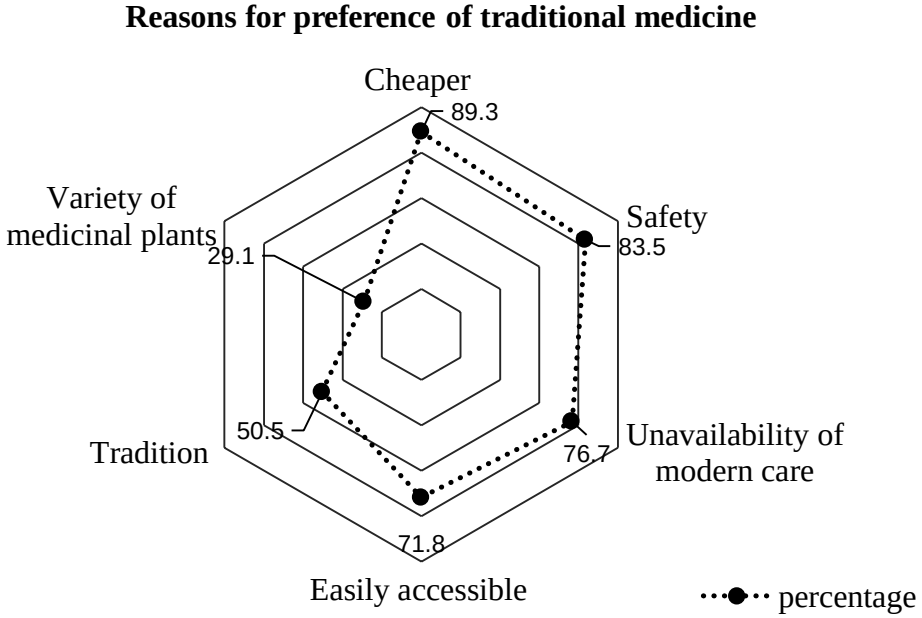

Figure 5: Radar chart showing reasons for preference of medicinal plant treatment over modern health care services

4.1.4 Information on the availability of medicinal plant *Z. chalybeum* to the community

Fifty four percent of respondents pointed the plant to be moderately available compared with the past 10 years while 31.8% and 14.02% mentioned to be the same and very difficult to be found respectively. Most of the respondents pointed forest (79.6%) and grazing lands (64%) as the main areas where they collect the plant while few of the respondents mentioned own farms (18.4%) and homestead (14.5%) as the main source. Furthermore, 76.7% respondents agreed that there were places the plant was available in past ten years but not anymore as caused by change in land use to agriculture (93.2%), overexploitation (77.6%), unsustainable harvesting methods (64.07%) and increase in demand (68.9%) (Fig. 6).

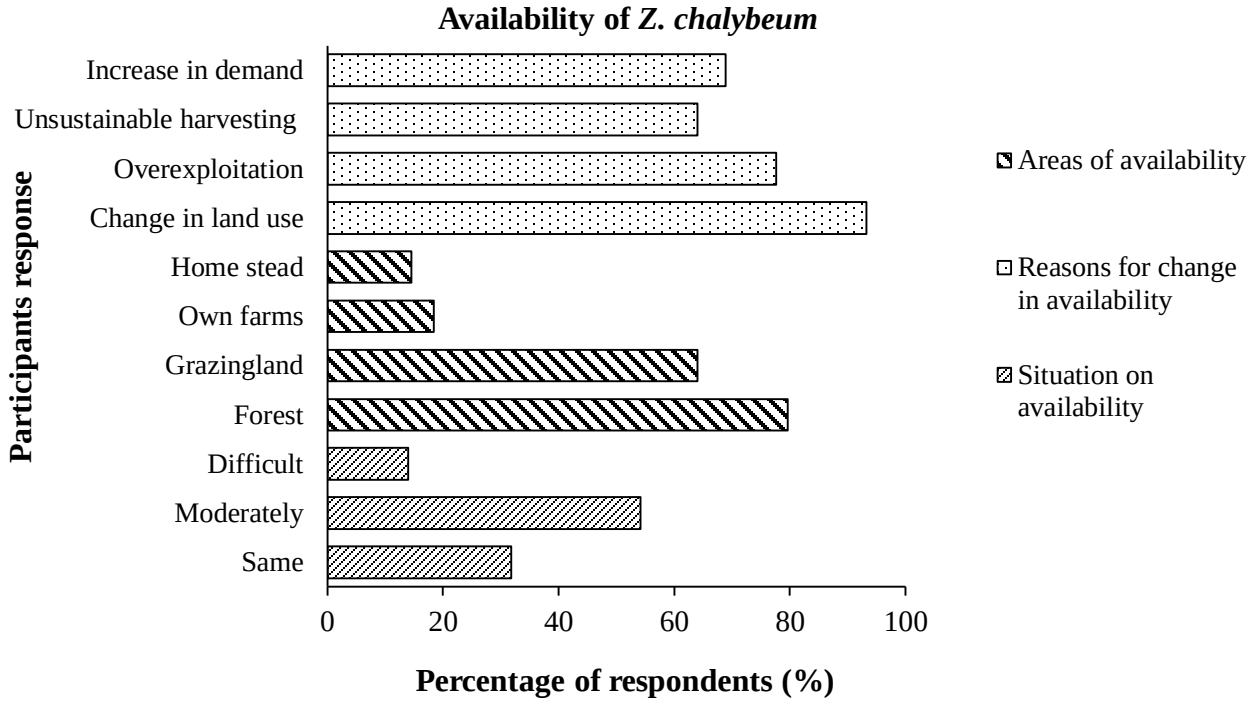

Figure 6: Represents the percentage (%) of respondents on situation of plant availability, reasons for change in availability and areas where they find the plant for harvesting

4.1.5 Information on challenges and conservation measures revealed by respondents

In this study information on people's insight on plant conservation through domestication was also collected in order to understand a clear picture on how community members perceived domestic conservation. Among respondents 54.4% agreed on domestication/cultivation while 45.6% disagreed reasons being, germination challenges (52.4%), lack of land (5.4%), lack of knowledge on tree propagation (17.5%) and lack of interest (26.2%). According to data gathered from key informants discussion, conservation of medicinal plants in the area face many challenges such as change in land use to agriculture (99.9%), wild fires and charcoal burning (71.4%), poor government support on conservation (42.8%), unsuitable harvesting methods (71.4%), poor generation of medicinal plants (57.1%) and lack of conservation awareness among locals (85.7%) (Fig. 7).

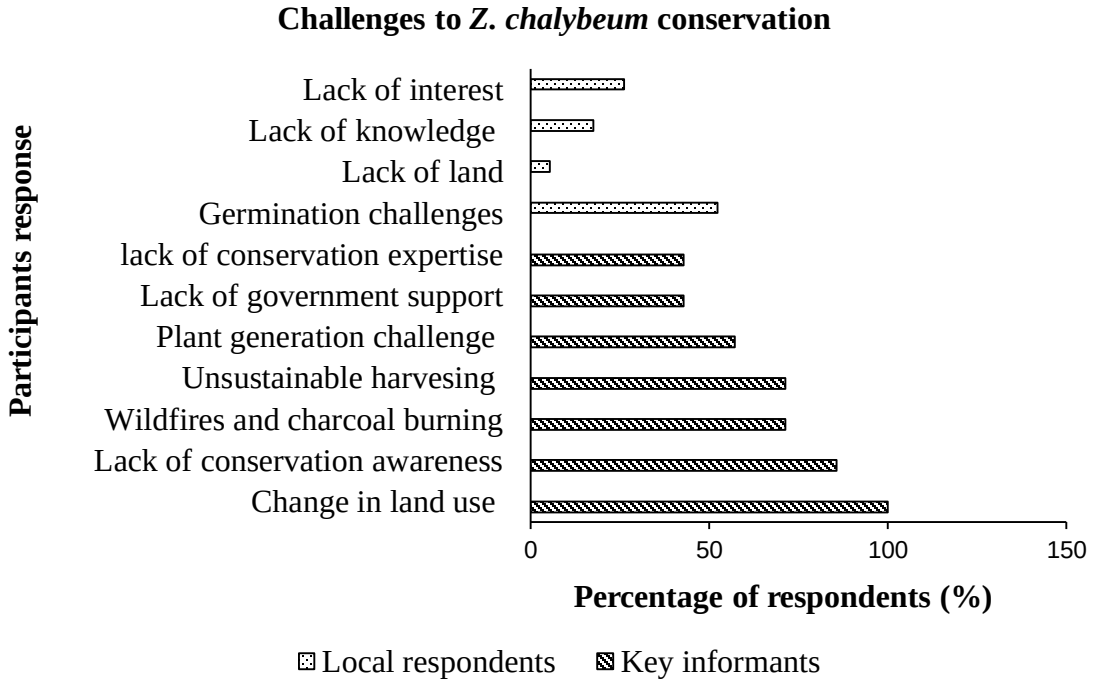

Figure 7: Challenges facing conservation of medicinal plant *Z. chalybeum* at Simanjiro area as pointed by local respondents and key informants

The conservation of medicinal plants was pointed to be important because medicinal plants provides employment among Maasai as herbalists (57.1%), it conserves the culture of Maasai (43%), source of all other modern medicines (43%) and it also help to conserve other natural resources (28.5%). Means of propagation mentioned by community members who have knowledge on plant propagation included seeds (22.3%), seedling (35.9%) and roots (15.5%). In order to conserve medicinal plants, different views where suggested by respondents such as provide education and awareness about conservation among locals (98.1%), reduce excessive harvesting (87.4%), while suggestions from key informants where; government should set rules and regulations for conservation of medicine plants (57.1%), ensure proper land use and land use planning (71.4%) and domestication (71.4%) (Fig. 8).

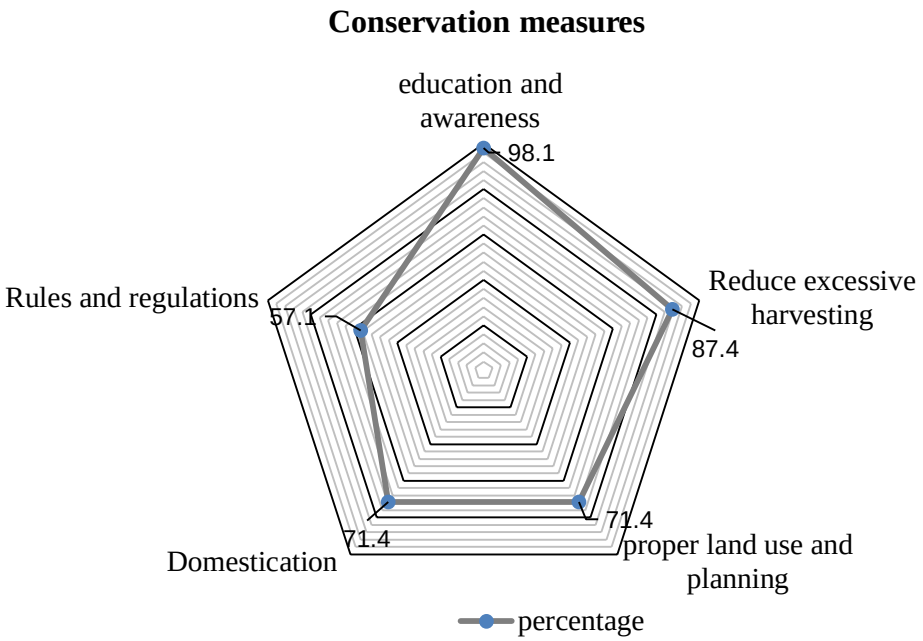

Figure 8: Radar chart showing conservation measures of medicinal plant *Z. chalybeum* as suggested by local community members and key informants

4.1.6 Distribution of *Z. chalybeum* trees across surveyed land use types at Simanjiro area

Simanjiro area as a whole has two major land use categories which are Game controlled areas and Open areas (Fig 9 & 10). Within these two major land use categories, there are other lands uses interwoven within the two main-land use types which were; settlements, grazing land and farm lands (Fig 9). Total of 501 sampling plots were observed in this study whereby 23.8 % of the sampling points had trees present while 76.1% tree absence. Within sampling points where trees were observed, 47% and 52.9% of trees were undamaged and damaged respectively. Most *Z. chalybeum* trees were more observed in low lands and middle hill areas rather than in slopes and shrubs in the areas surveyed. There was a significant difference in the distribution (present-absent) of *Z. chalybeum* per sampling plots established ($F_{(1, 42)} = 12.94$, $p = 0.0008$) across land use types encountered. Majority of *Z. chalybeum* trees were observed in game-controlled areas and open areas (situated within hunting blocks) compared with other land use types (Fig. 9).

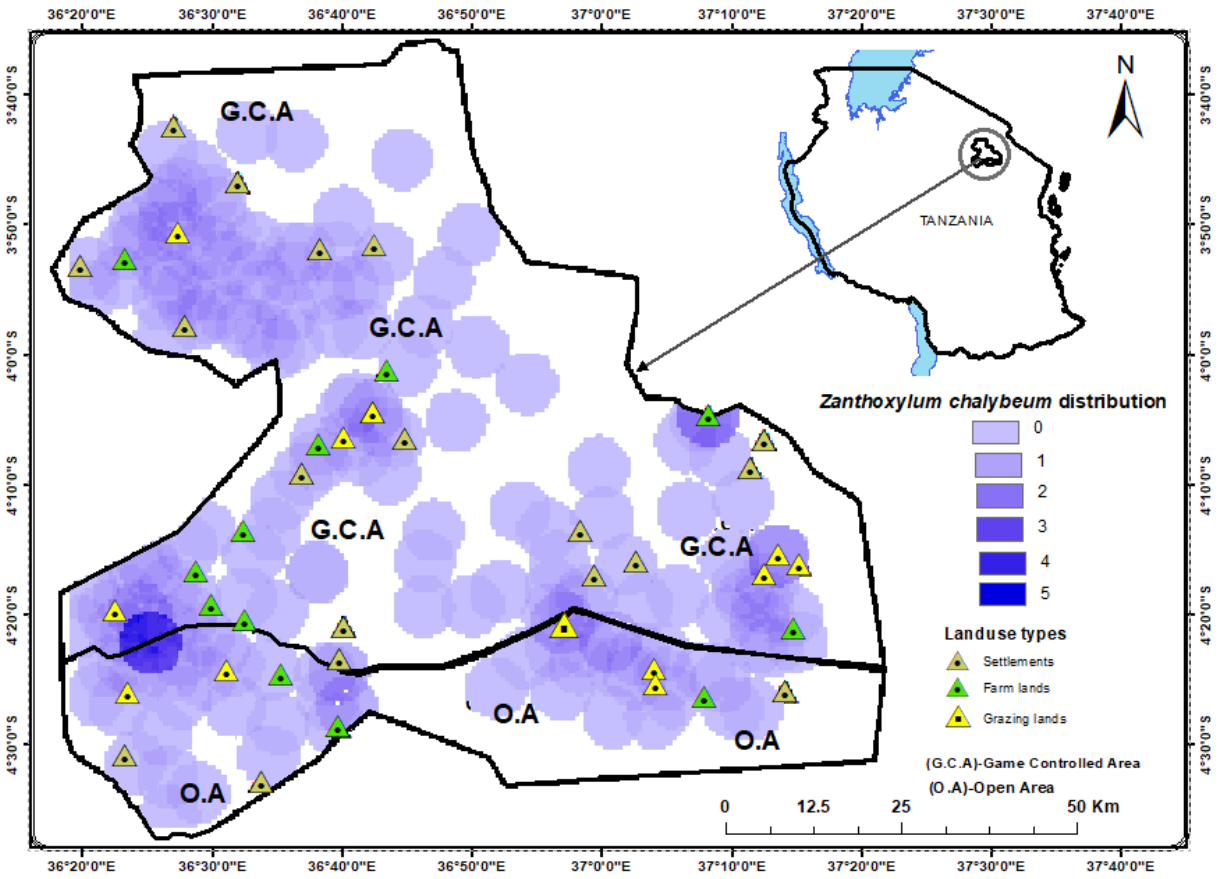

Figure 9: Map showing distribution (present- absent) of *Z. chalybeum* trees in Simanjiro area under different land uses

Few number of *Z. chalybeum* trees were distributed on farming lands. High distribution of damaged trees and damage level (scaling) was observed in grazing lands and farmlands while partial damages was observed in settlement areas (Fig. 10).

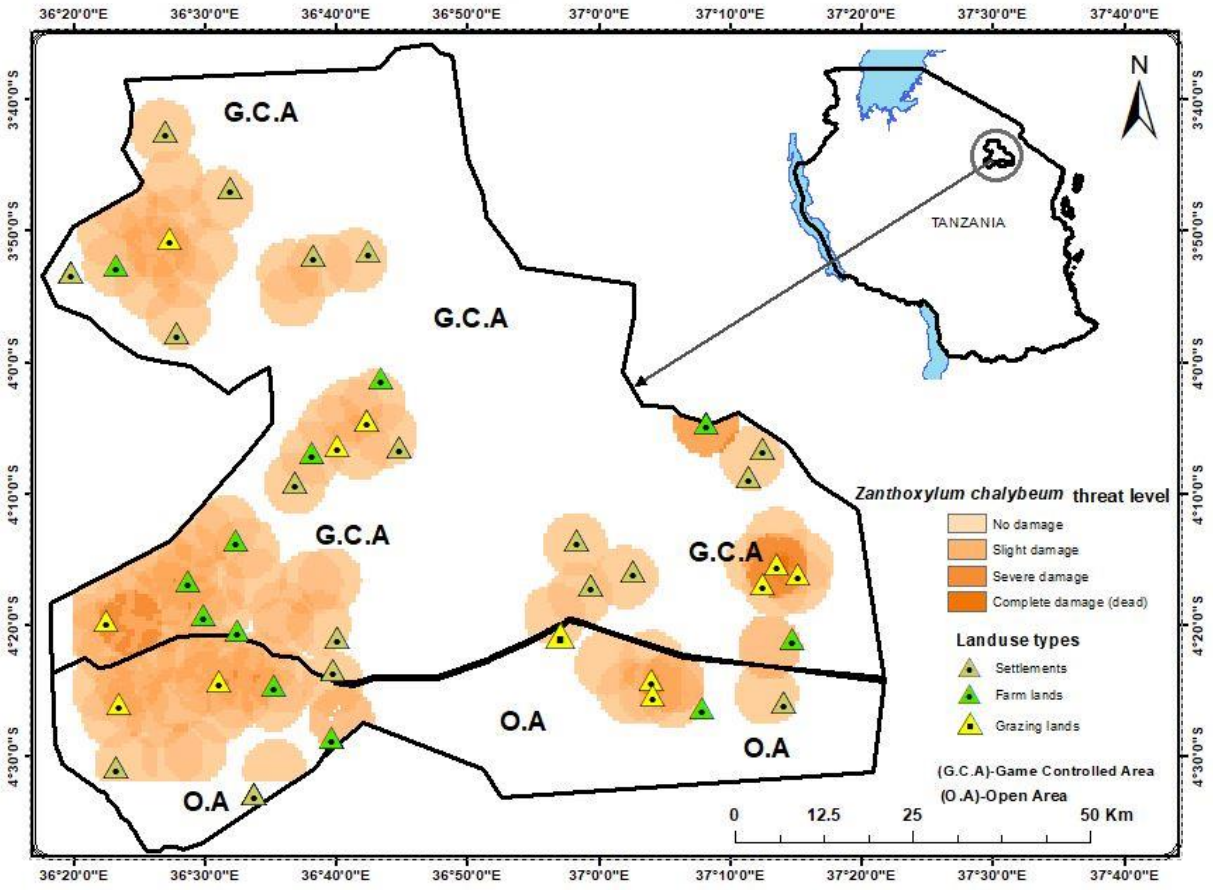

Figure 10: Map showing anthropogenic threats occurrence related to damage scale of *Z. chalybeum* trees in Simanjiro area under different land uses

4.1.7 The observed number of *Z. chalybeum* trees across sampled areas

Each encountered tree in the sampling point was counted individually, a significant difference ($p < 0.05$) in the total count of individual trees was observed in different land uses that were surveyed in the study area (Fig. 3). A significant number of *Z. chalybeum* trees were observed in game controlled areas (49) and open area (40) compared with other land uses categories; settlement (17), grazing lands (15) and farmlands (13) (Fig. 11).

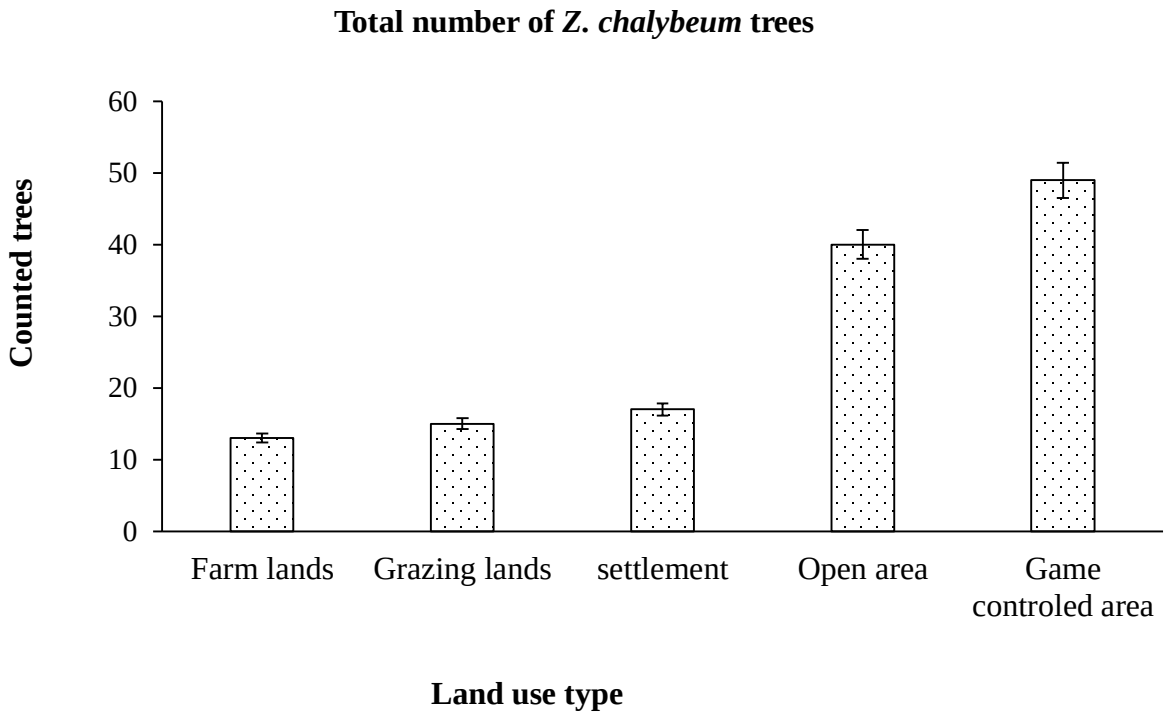

Figure 11: Total number of *Z. chalybeum* tree encountered in each sampling point in surveyed land use type at the study area

4.1.8 Observed anthropogenic threats signs, frequency of the threat and threat damage scaling level

Several anthropogenic threat signs such as debarking, branch cut, uprooting and harvest of the whole tree (whole tree cut) were observed in study sites (Plate 3). Many trees observed were debarked and few uprooted, branch cut and or whole cut (Fig. 12).

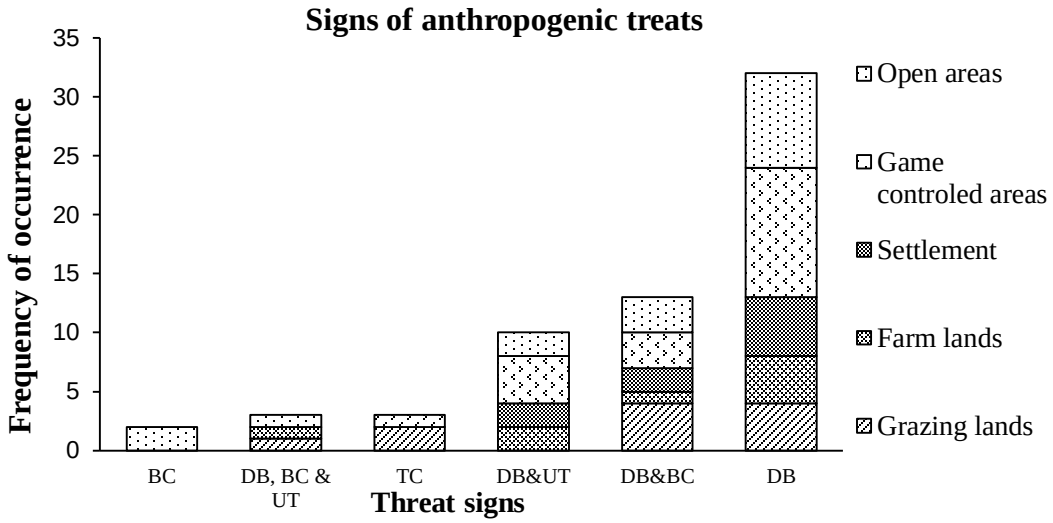

Figure 12: Anthropogenic threat sign and frequency of occurrence in each land use encountered. Key: BC= branch cut, DB=debarking, DB & BC=debarking and branch cut, DB & UT= debarking and uproot, DB, BC & UT= debarking, branch cut and uproot, TC= whole tree cut

Generally, there was no significant difference between the overall count of affected and unaffected trees (χ^2 =7.63, *df* = 4, *p* = 0.10) but there was a significant difference (χ^2 =12.9, *df* = 5, *p* = 0.02) between counts of affected and unaffected trees within land-use types (Fig. 13).

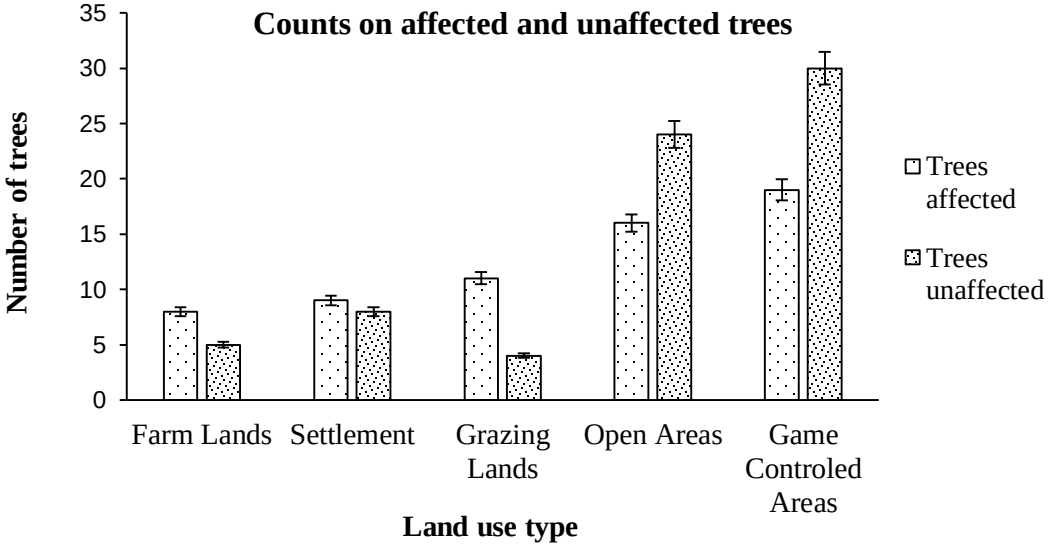

Figure 13: Total number of affected and unaffected *Z. chalybeum* tree encountered within each sampling point in different land uses

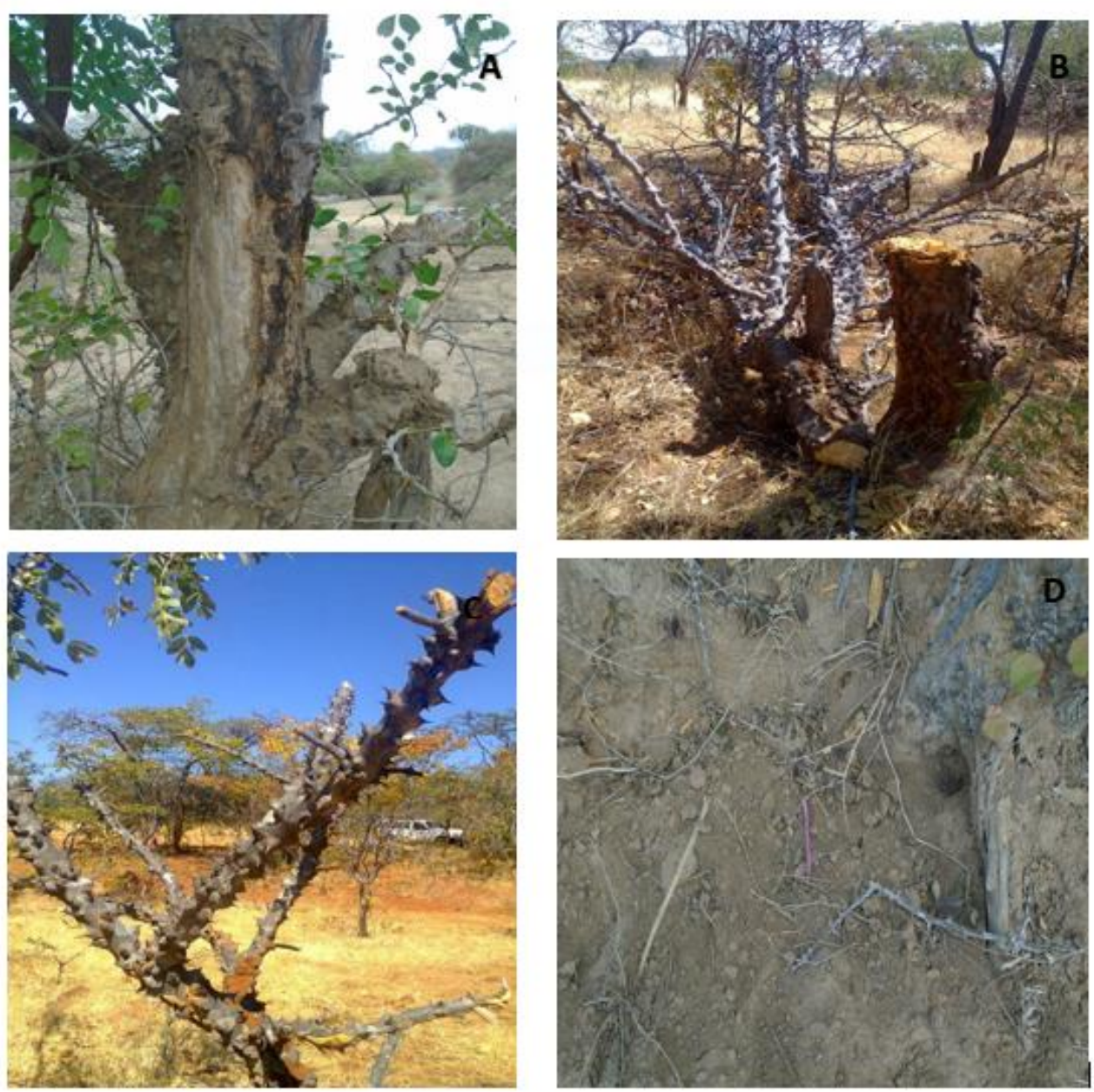

Plate 3: A- Debarked *Z. chalybeum* tree, B- whole tree cut down, C- Branches of the tree has been cut for harvesting seeds and D- a scar left after uprooting of the tree

Massive threats were observed in grazing lands and farm lands (73% and 62% respectively) while least threats were observed in Game controlled areas and Open areas (39% and 40% respectively). Majority of trees were debarked (51%) while other trees had a combination of threat signs such as debarking and branch cut (20.6%), debarking and uprooting (15.8%), debarking, branch cut and uproot (4.76%), whole tree cut (4.76%) and branch cut (3.17%). Tree damages differed significantly ($\chi^2 = 25.05$, $df = 12$, $p = 0.01$), whereby 30%, 13% and 4% under scale damage of (1)

- slight damage-few scars, (2) - severe damage-scarred deeply and (3) - tree completely damaged-dead respectively was observed while 53% of trees where having scale 0 - no damage (Fig. 14).

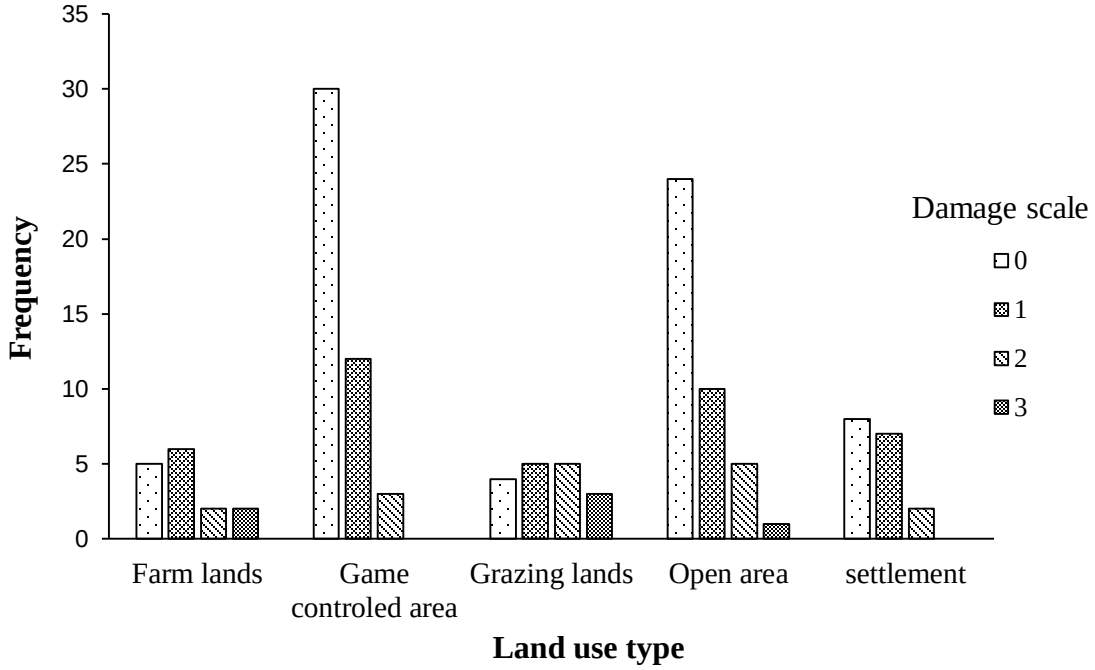

Figure 14: Scale of damage per tree and its frequency encountered in each land use (0 - no damage, 1- slight damage - few scars, 2-severe damage - scars deeply and 3 - tree completely damaged - dead)

4.2 Discussion

4.2.1 Characteristics of respondents with respect to their dependence on medicinal plants

The results, show that the majority of respondents had a primary level of education and some did not attend school at all (Table 1). This can influence their dependence on natural resources and therefore jeopardize *Z. chalybeum* conservation efforts. According to Ngondya *et al*. (2011) an environmentally educated person knows ecology, the values influencing it and can contribute positively to the application of ecological conservation. Further, it has been reported that the education level of an individual tends to impact the rate of adoption of new conservation and management techniques of natural resources including medicinal plants (Brewer, 2006). Low levels of education also hinder the chances of formal employment and thus force members to depend on natural resources to employ themselves (either as herbalist or charcoal sellers) which both limits conservation.

4.2.2 Uses and harvesting of medicinal plant *Z. chalybeum*

Zanthoxylum chalybeum trees are being used to treat women health complications (e.g. blood loss after labor, menstrual pain, early pregnancy complications), body ache, fever, pneumonia, dizziness, chest pain, body immunity, malaria and abdominal pain similar diseases have been reported by Dharani *et al*. (2010), Laltaika (2011), Nahashon (2013) and Balama (2016). The main method for drug preparation includes decoction. The decoction method has been used by many ethnobotanists because it has been effective in extracting the chemicals materials present in the plant part (Avwioro, 2010). Furthermore, roots and stem bark are the most used parts of the plant for medicinal remedies preparations because of belief on effectiveness in curing diseases, similar to Kitula (2007) and Engeu *et al*. (2008) reports. Nevertheless, the higher utilization of plant stem barks and roots for medicine can have deleterious effect to the survival of herbal plants unless sustainable utilization is implemented. According to, utilization of stable plant parts such as tubers, roots, bark or propagative parts for use as a source of medicines can endanger plant inhabitants or species sustainability (by causing death, stagnant growth, wilting and species extinction) thus sustainable harvesting should be well-thought-out (Tabuti *et al*., 2003; Shrestha & Dhillion, 2003; Crusesanders *et al*., 2005). This implies that *Z. chalybeum* is under threat to local extinction since roots and bark are main plant parts being harvested and thus, alternative tree planting around the

homestead, incorporation of the tree into agroforestry and agro-agriculture practice, education and awareness creation are conservation suggestions that will help reduce the pressure of harvesting to ensure plant stability.

4.2.3 Preference between traditional medicine and modern health care

The majority of respondents preferred traditional medicines than modern medicines (Fig. 5), reasons being; traditional medicines are cheaper, safer and accessible and are of many varieties than modern medicines, unavailability of adequate modern care systems and for conserving their tradition. Similar observation were reported by Kitula (2007), Augustino *et al.* (2014) and Makule (2018). Most of Tanzania rural residences have low income and face challenges of advanced technology in transportation, water availability, electricity and modern health systems. This was also observed in the study area during field surveys whereby the availability of hospitals and means for transportation was difficult. As the population increase, the pressure on dependency on herbal medicine by rural people increases thus increases harvesting pressure which leads to species extinction as many of the plants are harvested in the wild.

4.2.4 Availability of medicinal plant *Z. chalybeum* to the community

From the results (Fig. 6) the main source of medicinal plants are wild areas such as in forests and grazing lands similar to report by Augustino *et al.* (2014), Makule (2018) and Roulette *et al.* (2018). The dependence of medicinal plants from the wild has in turn resulted in the disappearance of many resources because many plants are being harvested unsustainably and no records are made (Makule, 2018). However, few families have engaged in domestication by planting Z. *chalybeum* in their home surroundings for easy accessibility, thus implies an awareness of conservation. Therefore, this underline the call for more education and training to community members on plant domestication possibilities and sustainable utilization methods for medicinal plants either by harvesting other plant parts (example seeds and leaves).

4.2.5 Challenges and conservation measures of medicinal plant *Z. chalybeum* in the area

Several major conservation challenges mentioned are due to change in land use to agriculture, overexploitation, unsustainable harvesting methods and increase in demand for medicinal plants

as reported by (McMillen, 2012; Nahashon, 2013; Makule, 2018). Other conservation challenges included wildfires and charcoal burning, poor government support for motivating conservation, unsuitable harvesting methods, poor generation of medicinal plants and lack of conservation awareness among locals. Conservation through domestication has been suggested by many conservationists, but the response has been low reasons being germination challenges, lack of land, lack of knowledge on tree propagation and lack of interest (Tchoundjeu *et al*., 2010). Moreover, propagation by using seeds in many cases showed challenges in germination as reported by Datt *et al*. (2002). Reasons such as hard seed coat and the low germination rate were also reported by respondents at Simanjiro District. This was also observed in the field survey where few tree sapling were observed out of 134 trees that were observed. These may somehow slower the domestication conservation campaigns, thus more efforts on conservation in the wild should be heavily promoted and also research on enhancing seed germination are encouraged. Referencing the results above, conservation measure stated such as the provision of education and awareness, reduce excessive harvesting and according to key informants, suggestions included government should set rules and regulations for the conservation of medicinal plants, ensure proper land use and land use planning and domestication, aligning with (McMillen, 2012; Mahunnah *et al*., 2012; Rajan & Kumarasamy, 2012) reports. Therefore, immediate conservation implications must be taken to ensure the continuation of plant availability.

4.2.6 Distribution of *Z. chalybeum* tree in Simanjiro area

The presence of hunting blocks within game-controlled areas and open areas that are managed by several hunting companies that perform periodic patrol could have positively influenced the vast distribution of *Z. chalybeum* within game-controlled areas and open areas compared with other land use types (Personal Observation). The presence of protected areas, therefore, ensures the effective exploitation of natural resources compared with unprotected areas (Cunningham, 2001; Hamilton, 2004; Kaky & Gilbert, 2016). Few numbers of trees observed in farmlands and settlements can be due to land clearing for crop cultivations (Personal Observation). According to McGeoch *et al.* (2008), land clearing for agriculture contribute significantly to the loss of native trees. The small number of trees observed in farmland and settlement areas suggests that the tree is mostly affected by excessive exploitation by humans for different uses. During the fieldwork, local communities confirmed several uses of the species including cough treatment, stomach-ache,

fever treatment, preventing vaginal bleeding, tea spice and sometimes seeds are fodder to goats. Our results conform with a study by Okigbo *et al*. (2008) and Saqib *et al*. (2011) whose findings suggested that there will be a decrease in the distribution of *Z. chalybeum* if settlement expansion and low conservation awareness was among local communities. This may also be the case with Simanjiro area because, not all members of the communities understand the consequences of excessive exploitation on the species survival and persistence.

Interestingly, the majority of trees that were found in settlement areas were reported to be planted, this highlights the potential for engaging local people on conservation of *Z. chalybeum* through domestication as such efforts have been reported as a successful conservation strategy for most medicinal plants (Makule, 2018). Domestication of *Z. chalybeum* will not only ensure its accessibility but also will secure the tree during the times of needs (Amujoyegbe *et al*., 2012) and hence ensure its conservation (Okigbo *et al*., 2008). Lowest number of trees were observed in grazing lands as a consequence of livestock grazing. Grazing has been reported to negatively influence species composition, distribution and biomass (Sher *et al*., 2010; Ganie *et al*., 2019). Generally, the overall distribution of the tree in all surveyed land uses types was very low mainly because the tree is highly favored by the community as a remedy for different diseases (Laltaika, 2011; Makule, 2018). Therefore, there is a possibility for a continuous decrease in the distribution of *Z. chalybeum* in the future if no effective conservation campaigns will be initiated.

4.2.7 Anthropogenic threats facing *Z. Chalybeum* in Simanjiro area

The relationship between the harvesting method and the plant part being harvested and its impacts on the natural wild plants have been observed in many cases (Rai *et al*., 2000; Rahman *et al*., 2011). It has been documented that, the effects of unsustainable harvesting methods on plants include wilting, stagnant growth and sometimes may result in plant death (Rahman *et al*., 2011). In this study, debarking was observed in many cases compared with other threats and this could be due to the presence of active compounds in *Z. chalybeum* bark (Moshi & Mbwambo, 2002; Bbosa *et al.*, 2014) compared to other parts. Debarking of plant stem has been reported to cause negative effects on the plant such as blocking of translocation of materials, which is necessary for healthy growth and survival of the plant, increased insect attack, limits survival rate of the tree and can eventually lead to plant death (Purohit *et al.*, 2001; Delvaux *et al*., 2009).

The highest frequency of anthropogenic threats was observed in grazing and farming lands compared to other land use types due to easy accessibility (Cunningham, 2001; Sher *et al*., 2010). On the contrary, the observed low number of threats in trees grown in settlement areas can be due to the owner's protection of the trees from massive harvesting (Personal Observation). Although there were few observations of *Z. chalybeum* uprooting signs, *Z. chalybeum* tree roots have been harvested for treatment purposes (Laltaika, 2011; Makule, 2018). Observation of *Z. chalybeum* uprooting signs in the field was few and this could be related to the fact that people tend to cover uprooting signs (McGeoch *et al*., 2008). The damage scales (Fig. 14) indicate that people are aware of the effects of unsustainable harvesting methods (Personal Observation) therefore if well informed will contribute much to the conservation of *Z. chalybeum*. It seems that local demand influenced by increased population and population pressures has fueled the unsustainable harvesting for both commercial and household use.

According to respondents, Oloisuki (*Z. chalybeum*) is not just any other tree as the plant has been utilized for medicinal purposes for over centuries. The preference of use of *Z. chalybeum* over other medicinal plants has also been reported in the studies conducted in Northern Tanzania by (Laltaika, 2011; Makule, 2018; Roulette *et al*., 2018). Furthermore, the findings revealed that community member depends on natural treatment compared to modern methods (Makule, 2018). The high demand and methods used for harvesting are not suitable and thus leaves scars and damages that are easily observed of which can cause serious effects on the plant as discussed in part 4.2.6 above. The community agrees to conduct harvesting in the wild areas, of which, the demand growth and change in land use have also led to the fading and declining of the tree within areas that were formerly densely with the species population. From the discussion above, it thus shows how important plant conservation is needed referring to the fact that, the demand increases and land-use changes will still face the community. In addition to increased community conservation and education awareness, active planting of the tree in and around settlement areas would help reduce harvesting pressures in the wilderness.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study has highlighted the distribution and anthropogenic threats facing medicinal plant *Z. chalybeum* at Simanjiro area and has also reported possible conservation challenges and measures to be taken to ensure plant sustainability. In this study it was observed that, traditional medicine is a preferred form of primary medical care as compared to modern health. The high dependency and steady increase in demand on medicinal plants shown by members at Simanjiro area also call for strategies to protect the plants and for measures to promote their sustainable utilization. The study also indicates the role of protected areas in the conservation of natural resources. It was observed that protected areas have contributed significantly to the distribution of the tree at Simanjiro area. The current observation in this study also shows that the rates of harvesting are increasing and harvesting methods used by community members are unsustainable. The observed signs of debarking, uprooting, tree cut and branch cut signify *Z. chalybeum* extinction risk if no immediate conservation efforts will be taken.

Also, documentation of plant parts used, traditional medicinal uses and drug preparations were achieved. It was also observed that some have engaged in medicinal plant domestication in their home/farmstead and partial care is taken during harvesting of medicinal plants as a means for sustainable utilization. This emphasizes the existence of conservation awareness among community members.

5.2 Recommendations

This study recommends more conservation efforts to be implemented in Simanjiro areas with particular focus on enforcing regulations in game controlled areas and open areas as they are seen as the resource bank of the tree in the study area. Promotion of cultivation and conservation of the species in farmland would help reduce the harvesting pressures in protected areas, while providing access by local community in their own farms. Local and other authorities should use results generated from this study as a baseline to promote conservation strategies of medicinal plant *Z.*

chalybeum at Simanjiro area. More efforts should be directed on creating conservation awareness among locals and if possible, the government should set regulations that will guide the use and exploitation of *Z. chalybeum* especially as it is being excessively exploited in the wild. Furthermore, encouragement on medicinal plant domestication should be of priority so that to have a resource bank of medicinal plant availability instead of depending resource from the wild only. Furthermore, avoiding ring barking, harvesting of few roots per plant, cover soil after digging and harvesting of the bark from opposite quarters of the stem are measures that can be adopted by members for sustainable harvesting. However, this study recommends future research on;

(i) Impacts of bark removal on the survival of *Z. chalybeum* as a base for suggesting proper debarking level that may not cause serious damage to the plant.

(ii) Population structure of *Z. chalybeum* in all possible areas of existence.

(iii) Test and establish effective propagation mechanism that can be adopted for tree domestication.

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APPENDICES

Appendix 1: Questionnaire for local respondents

SECTION 1: PERSONAL INFORMATION

Name …….

Gender a) MALE, b) FEMALE

Age a) 18 - 30 years b) 30 – 60 years c) Above 60 years

Education level of the respondent, (a) Secondary level (b) Primary level (c) Adult education e. None (f) Other (specify)

Occupation: a.Midwife b. vendor c. pastoralist d. Business e.traditional doctor f. Jobless

Sub village…….

SECTION 2: USAGE AND AVAILABILITY

2) Do you know *Zanthoxylum chalybeum (*Oloisuki) tree

a) Yes
b) No

3-a) Do you utilize the tree for traditional medicines?

a) Yes
b) No

3-b) If yes, list the use of this plant for treating any disease that you know, Which part of the plant do you use for treating diseases? How is the medicine for this plant prepared? Explain

Diseases cured 1-malaria, 2-women health complications, 3-tooth pain, 4-diabetes, 5-cough, 6-other(specify)	Part harvested 1=Leaf 2=Root 3=Bark 4-Other (specify)	Mode of preparation 1-drying, grinding and mix with water. 2-boiling 3-eating row 4-other(specify)

4-a) Is the plant being used for other purpose apart from medication?

a) Yes
b) No
c) Don't know

4-b) If YES in (a) above, what is it used for,

a) Timber
b) Fire wood
c) Furniture and ornaments
d) Others(mention)

4) What is the most preference use of the plant?

a) Medicine
b) Timber
c) Firewood
d) Others (mention)

5) How long can you walk to locate the tree?

a) Less than 30 minutes
b) Less than 1 hour
c) More than 1 hour

6) Is the intensity of use/harvest vary in seasons? if YES, what are the reasons,

a) Biomass accumulation
b) Demand change
c) Other (specify)

6-b) what is the most preference part of the tree being used?

a) Seeds
b) Stem bark

c) Leaves

d) Roots

6-c) why is one (above) more preferred than the other

…….

7a) What is the rate of preference in use of this plant compared to other medicinal plants?

a) Very high

b) High

c) Moderate

d) Low

7b) why do you prefer medicinal plants over modern health care

a) Easy accessibility

b) Long term knowledge

c) Modern care are expensive

d) More effective

8) What is the rate of harvest of this medicinal plant?

a) Very high

b) High

c) Moderate

d) Low

9) Who are the most people using the plant for medication?

a) Females

b) Males

c) Children

d) All

10) Where in your area do you collect this plant for use?

a) Village land

b) forest

c) Own farm

d) Other(specify)

11) How is the status of plant availability compared to past 10 years?

a) Same

b) Difficult

c) Moderately available

12-a) Are there areas that the plant was once available but now it is not?

a) Yes

b) No ☐

c) Don't know

12-b) What do you think can cause scarcity on availability of the plant?

a) Unsustainable harvesting methods

b) Increase in demand/over exploitation ☐

c) Change in land use

d) Other (specify)

SECTION 3: WILLINGNESS, CHALLENGES and OPPORTUNITIES TO CONSERVATION OF MEDICINAL PLANT.

13-a) Do you think harvesting method you use has any effect to the plant?

a) Yes

b) No ☐

c) I don't know

13-b) If YES above, what are the effects

a) Wilting

b) Stunted ☐

c) death

d) other(specify)

14-a) Can the tree be established (propagated) outside their areas?

a) Yes

b) No ☐

c) Don't know

14-b) If YES above, what means can be used?

a) Seeds

b) stem

c) Roots ☐

d) Others (specify)

15) What methods do you use for sustainable utilization of medicinal plants?

a) Pass the knowledge to the youth
b) Plant trees around the homestead or farms
c) Reduce excessive harvesting
d) Other (specify)

16) What should be done to ensure sustainable utilization of medicinal plants in your area?

a) Training
b) Domestication
c) Nothing
d) Other (specify

17-a) Are you willing to contribute for conservation through domestication?

a) Yes
b) No

17-b) If NO above, what is the reason,

a) Lack of knowledge
b) Not interested
c) Lack of land
d) Germination challenge

18) In your opinion, what can be done to sustain the plant in your area?

……

……

……

……

**********The end, thank you for your cooperation**********

Appendix 2: **Questions for key informant interview (district forest office, existing conservation NGO's and elders >60)**

1. Do you know a tree called Oloisuki?
2. Have you ever used this tree as a medicine or any other use?
3. Are medicinal plants highly preferred by local communities in your area?
4. Why do they prefer medicinal plants rather than modern medicines?
5. Where do most of community members collect Oloisuki/medicinal plants?
6. What is the trend of harvesting and availability of Oloisuki tree, is it increasing/ decreasing?
7. If increasing/ decreasing, what could be the driving factors?
8. Is conserving Oloisuki/ medicinal plants important?
    a. Yes: Why …….
    b. No: Why ……..
9. What are the challenges facing efforts of conserving Oloisuki / medicinal plants in your area?
10. What do you think should be done to conserve Oloisuki / Medicinal plants in your area?

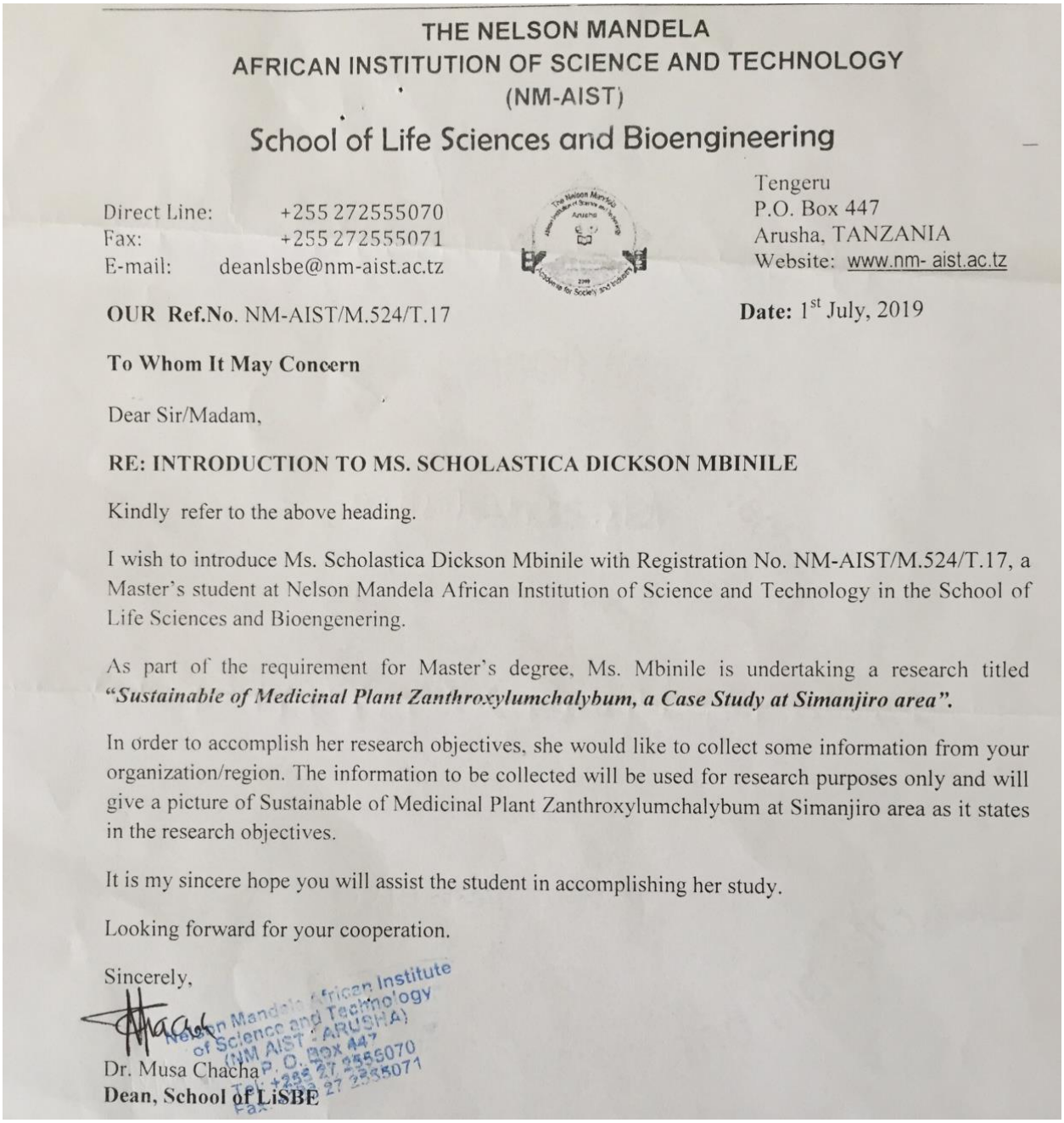
Appendix 3: **Field inventory data collection form.**

Recorder: …… Date: ……

Sampling plot number	Land use 1-Grazingland, 2-Communal land, 3-Open area, 4- Cultivation area, 5-Game controlled area, 6-Other (specify)	Threat 1-Debarking, 2-Uprooting, 3-Leaves harvest, 4-Fire damage 5-branch cut	Tree damage scale (0,1,2,3)

Where: (0)-no damage, (1)-slight damage-few scars, (2)-severe damage-scarred deeply and (3)-tree completely damaged-dead

Appendix 4: Student introduction letter from The Nelson Mandela African Institution of Science and Technology



THE NELSON MANDELA
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Arusha, TANZANIA
Website: www.nm- aist.ac.tz

OUR Ref.No. NM-AIST/M.524/T.17

Date: 1st July, 2019

To Whom It May Concern

Dear Sir/Madam,

RE: INTRODUCTION TO MS. SCHOLASTICA DICKSON MBINILE

Kindly refer to the above heading.

I wish to introduce Ms. Scholastica Dickson Mbinile with Registration No. NM-AIST/M.524/T.17, a Master's student at Nelson Mandela African Institution of Science and Technology in the School of Life Sciences and Bioengenering.

As part of the requirement for Master's degree, Ms. Mbinile is undertaking a research titled ***"Sustainable of Medicinal Plant Zanthroxylumchalybum, a Case Study at Simanjiro area".***

In order to accomplish her research objectives, she would like to collect some information from your organization/region. The information to be collected will be used for research purposes only and will give a picture of Sustainable of Medicinal Plant Zanthroxylumchalybum at Simanjiro area as it states in the research objectives.

It is my sincere hope you will assist the student in accomplishing her study.

Looking forward for your cooperation.

Sincerely,

Dr. Musa Chacha
Dean, School of LiSBE

Appendix 5: Research clearance form from Simanjiro district for Loiborsoit. A village

HALMASHAURI YA WILAYA YA SIMANJIRO

(*Barua zote zitumwe kupitia kwa Mkurugenzi Mtendaji (W)*)

Simu **:** 027-2552225
Faksi: 027-2555608
Baruapepe:
ded@simanjirodc.go.tz

Ofisi ya Mkurugenzi Mtendaji (W),
S.L.P. 9596,
ORKESUMET-SIMANJIRO.

Kumb.Na.HMW/SMJ/M/138/43 **11/07/2019.**

Afisa Mtendaji wa Kijiji cha Loiborsoit A,
Wilaya ya Simanjiro.

YAH: UTAMBULISHO WA MTAFITI WA KISAYANSI NDUGU SCHOLASTICA DICKSON MBINILE.

1. Tafadhali husika na mada tajwa hapo juu.
2. Mtajwa hapo juu ni mwanafunzi wa chuo cha Nelson Mandela anayefanya shahada ya Uzamivu katika fani ya sayansi ya Mimea. Atafanya utafiti juu ya mti aina ya Mjafari (Oloisuki) unaopatikana kwa urahisi katika eneo lako.
3. Kwa barua hii mpokee mwanafunzi huyu na kumpa ushirikiano ilikufanikisha utafiti huo.
4. Nakutakia utekelezaji mwema.

Naishorwa L. Muriatoi
Kny; MKURUGENZI MTENDAJI (W)
SIMANJIRO.

KNY:MKURUGENZI MTENDAJI
HALMASHAURI YA WILAYA
SIMANJIRO

Nakala;
Mkuu wa Wilaya ya Simanjiro – Kwa taarifa.
Mkurugenzi Mtendaji (W) Simanjiro – Aione kwenye jalada

Appendix 6: Research clearance form from Simanjiro district for Londrekess village

HALMASHAURI YA WILAYA YA SIMANJIRO

(*Barua zote zitumwe kupitia kwa Mkurugenzi Mtendaji (W)*)

Simu **:** 027-2552225
Faksi: 027-2555608
Baruapepe:
ded@simanjirodc.go.tz

Ofisi ya Mkurugenzi Mtendaji (W),
S.L.P. 9596,
ORKESUMET-SIMANJIRO.

Kumb.Na.HMW/SMJ/M/138/43 **11/07/2019.**

Afisa Mtendaji wa Kijiji cha Londrekess,
Wilaya ya Simanjiro.

YAH: UTAMBULISHO WA MTAFITI WA KISAYANSI NDUGU SCHOLASTICA DICKSON MBINILE.

1. Tafadhali husika na mada tajwa hapo juu.
2. Mtajwa hapo juu ni mwanafunzi wa chuo cha Nelson Mandela anayefanya shahada ya Uzamivu katika fani ya sayansi ya Mimea. Atafanya utafiti juu ya mti aina ya Mjafari (Oloisuki) unaopatikana kwa urahisi katika eneo lako.
3. Kwa barua hii mpokee mwanafunzi huyu na kumpa ushirikiano ilikufanikisha utafiti huo.
4. Nakutakia utekelezaji mwema.

Naishorwa L. Muriatoi
Kny; MKURUGENZI MTENDAJI (W)
SIMANJIRO.

KNY:MKURUGENZI MTENDAJI
HALMASHAURI YA WILAYA
SIMANJIRO

Nakala;
Mkuu wa Wilaya ya Simanjiro – Kwa taarifa.
Mkurugenzi Mtendaji (W) Simanjiro – Aione kwenye jalada

Appendix 7: Research clearance form from Simanjiro district for Namalulu village

HALMASHAURI YA WILAYA YA SIMANJIRO
(Barua zote zitumwe kupitia kwa Mkurugenzi Mtendaji (W)

Simu : 027-2552225
Faksi: 027-2555608
Baruapepe:
ded@simanjirodc.go.tz

Ofisi ya Mkurugenzi Mtendaji (W),
S.L.P. 9596,
ORKESUMET-SIMANJIRO.

Kumb.Na.HMW/SMJ/M/138/43 **11/07/2019.**

Afisa Mtendaji wa Kijiji cha Namalulu,
Wilaya ya Simanjiro.

YAH: UTAMBULISHO WA MTAFITI WA KISAYANSI NDUGU SCHOLASTICA DICKSON MBINILE.

1. Tafadhali husika na mada tajwa hapo juu.

2. Mtajwa hapo juu ni mwanafunzi wa chuo cha Nelson Mandela anayefanya shahada ya Uzamivu katika fani ya sayansi ya Mimea. Atafanya utafiti juu ya mti aina ya Mjafari (Oloisuki) unaopatikana kwa urahisi katika eneo lako.

3. Kwa barua hii mpokee mwanafunzi huyu na kumpa ushirikiano ilikufanikisha utafiti huo.

4. Nakutakia utekelezaji mwema.

Naishorwa L. Muriatoi
Kny; MKURUGENZI MTENDAJI (W)
SIMANJIRO.

KNY:MKURUGENZI MTENDAJI
HALMASHAURI YA WILAYA
SIMANJIRO

Nakala;
Mkuu wa Wilaya ya Simanjiro – Kwa taarifa.
Mkurugenzi Mtendaji (W) Simanjiro – Aione kwenye jalada

Appendix 8: Research clearance form from Simanjiro district for Naberera village

HALMASHAURI YA WILAYA YA SIMANJIRO

(*Barua zote zitumwe kupitia kwa Mkurugenzi Mtendaji (W)*)

Simu : 027-2552225
Faksi: 027-2555608
Baruapepe:
ded@simanjirodc.go.tz

Ofisi ya Mkurugenzi Mtendaji (W),
S.L.P. 9596,
ORKESUMET-SIMANJIRO.

Kumb.Na.HMW/SMJ/M/138/43 **11/07/2019.**

Afisa Mtendaji wa Kijiji cha Naberera,
Wilaya ya Simanjiro.

YAH: UTAMBULISHO WA MTAFITI WA KISAYANSI NDUGU SCHOLASTICA DICKSON MBINILE.

1. Tafadhali husika na mada tajwa hapo juu.

2. Mtajwa hapo juu ni mwanafunzi wa chuo cha Nelson Mandela anayefanya shahada ya Uzamivu katika fani ya sayansi ya Mimea. Atafanya utafiti juu ya mti aina ya Mjafari (Oloisuki) unaopatikana kwa urahisi katika eneo lako.

3. Kwa barua hii mpokee mwanafunzi huyu na kumpa ushirikiano ilikufanikisha utafiti huo.

4. Nakutakia utekelezaji mwema.

Naishorwa L. Muriatoi
Kny; MKURUGENZI MTENDAJI (W)
SIMANJIRO.

KNY: MKURUGENZI MTENDAJI
HALMASHAURI YA WILAYA
SIMANJIRO

Nakala;
Mkuu wa Wilaya ya Simanjiro – Kwa taarifa.
Mkurugenzi Mtendaji (W) Simanjiro – Aione kwenye jalada